# ASTRONOMY

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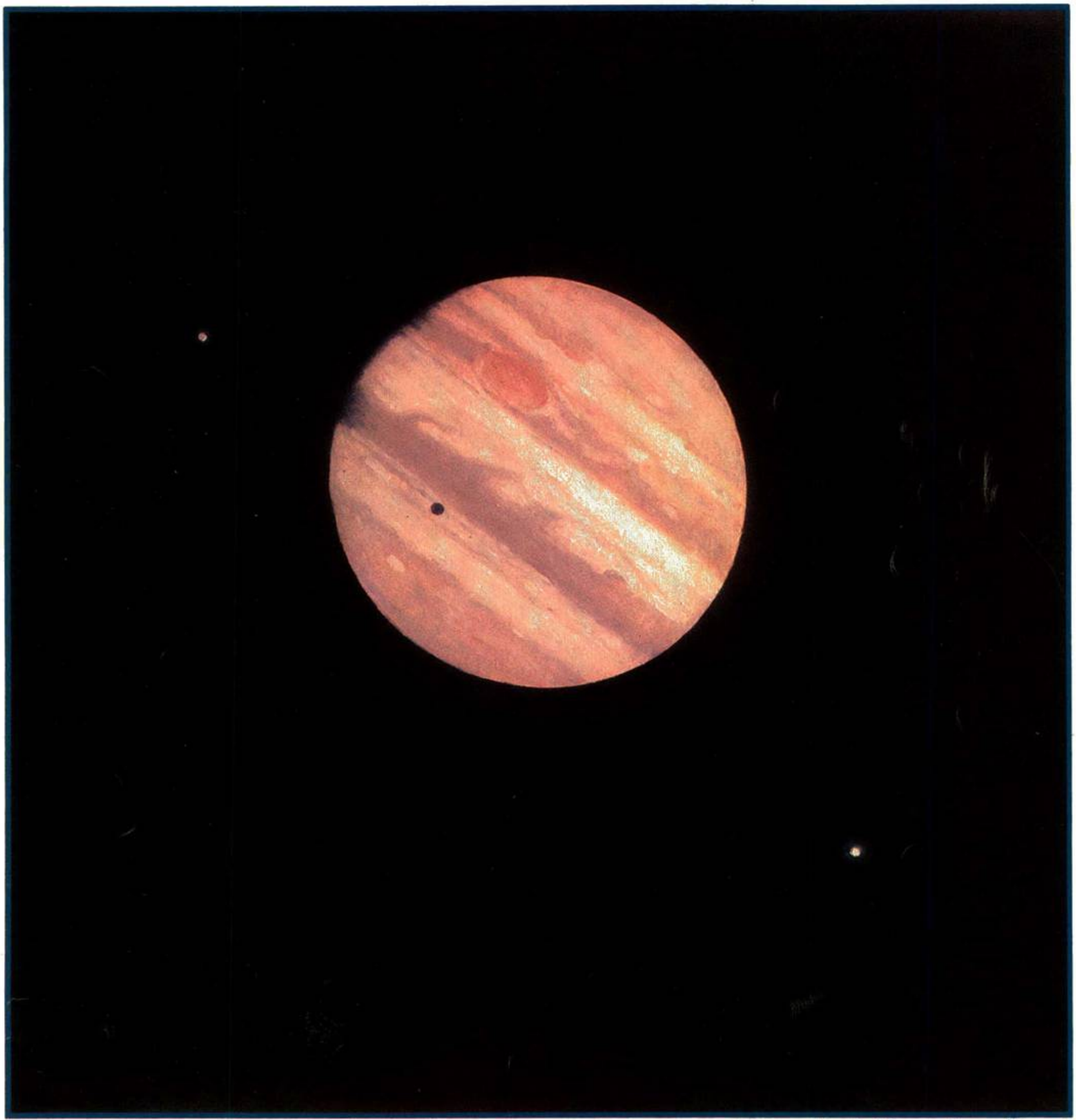

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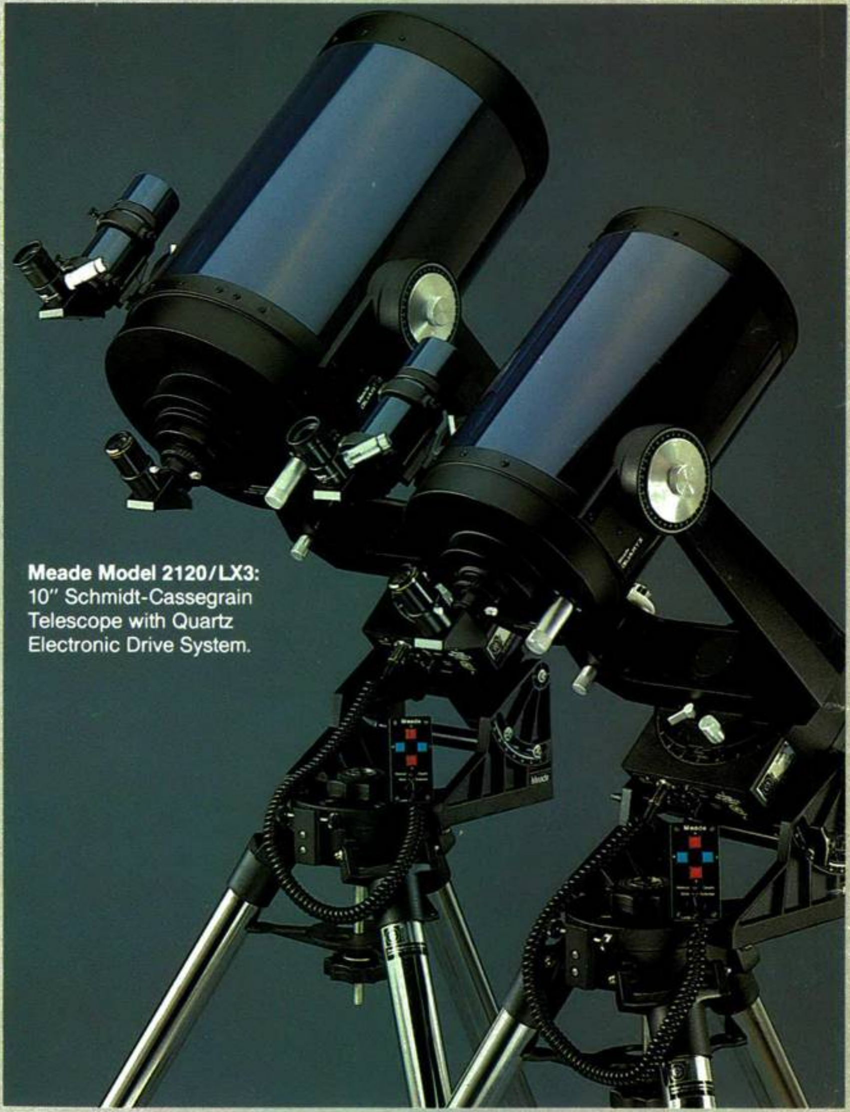

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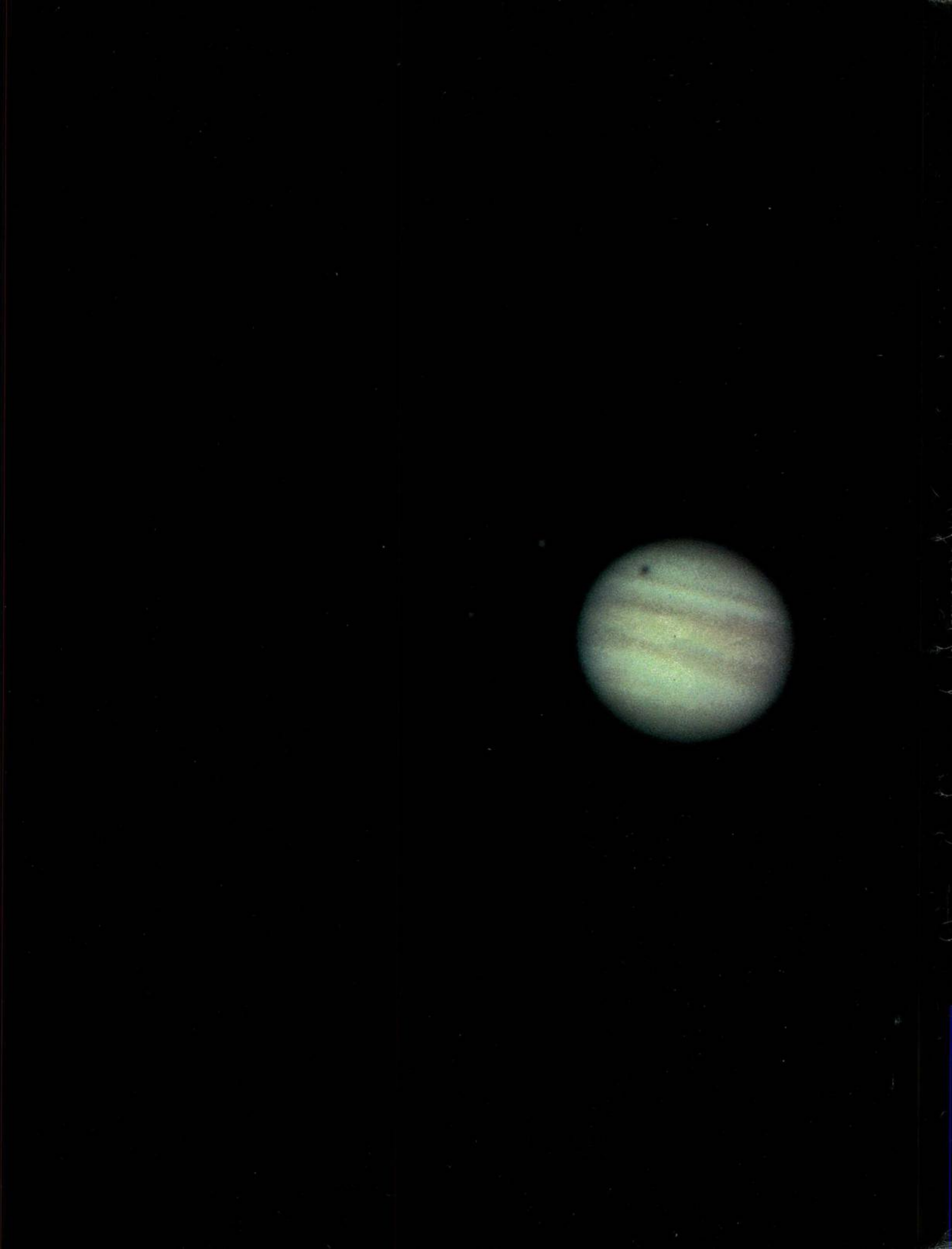

# ASTRONOMY

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**Cover:** As Jupiter makes its closest approach to Earth in twelve years, its disk will exhibit many cloud features that should be visible in 6- and 8-inch telescopes. Painting by Jim Hervat, based on a sketch by I. Miyazaki. These pages: Two Galilean moons and a shadow transiting the Jovian disk are visible in this photo by Craig Crawford.

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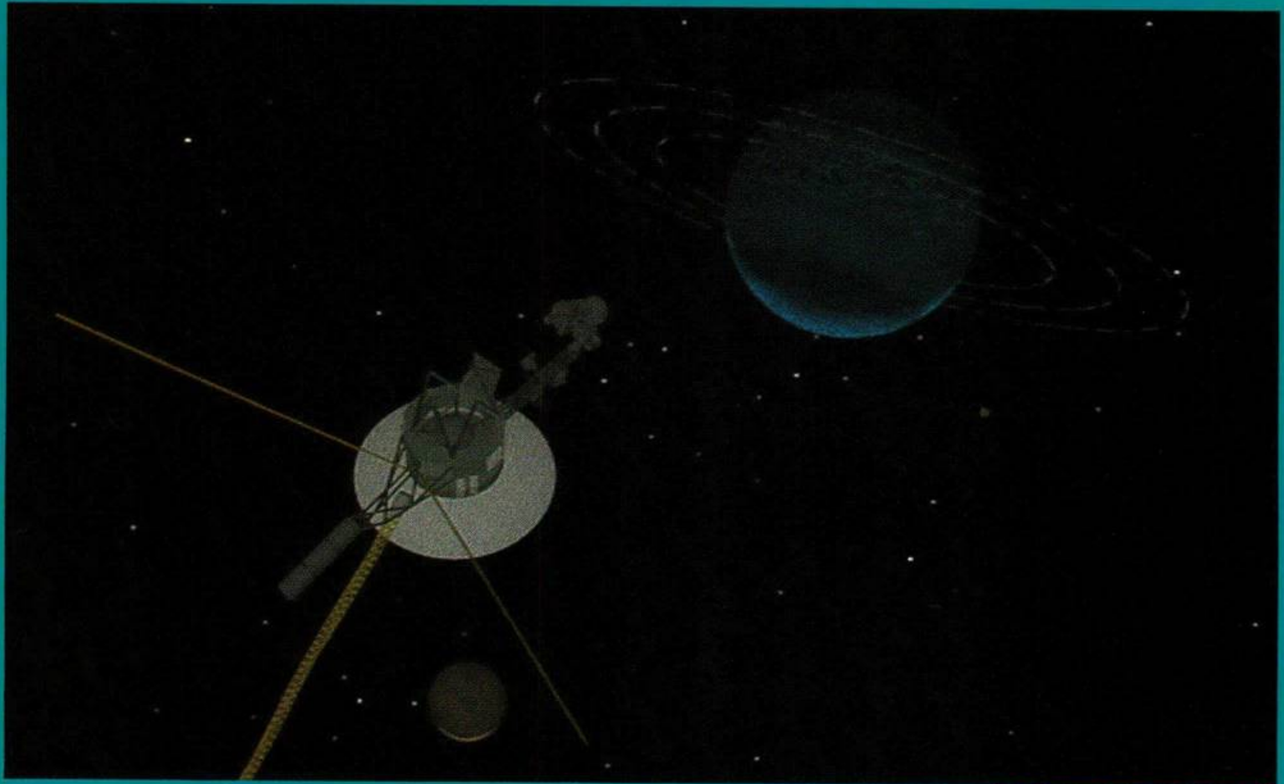
# AIMING FO



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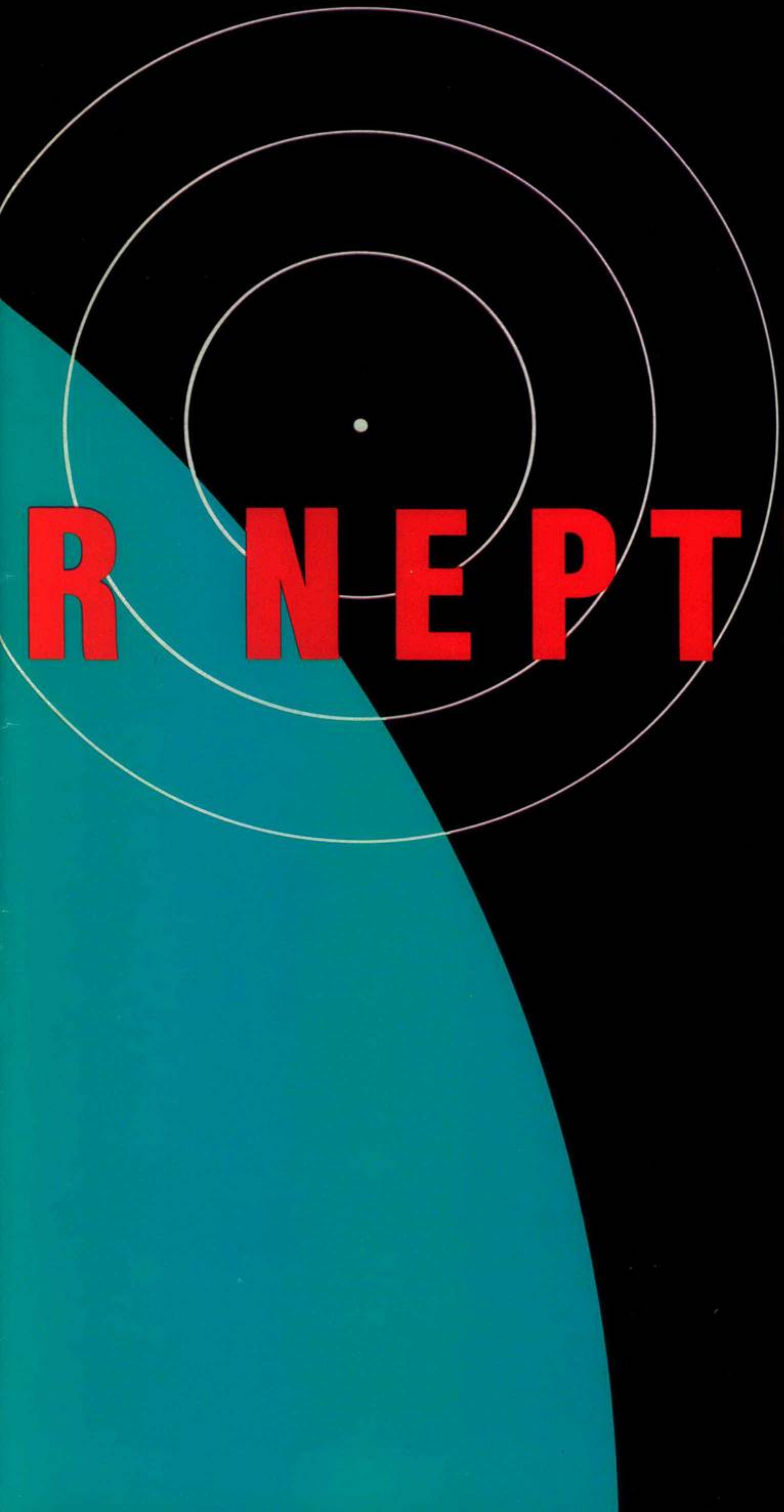


# R NEPTUNE

*Voyager's trajectory past Neptune is a compromise between maximum scientific return and spacecraft safety. How did mission planners select the best flight path?*

by Charles E. Kohlhase

After successful *Voyager* flybys of Jupiter, Saturn, and Uranus, flying the spacecraft safely by a planet may seem like nothing out of the ordinary. But planning *Voyager 2*'s encounter with Neptune in 1989 has proven to be anything but "old hat." Deciding how to get the maximum scientific return without risking the spacecraft is a tricky business.

The success or failure of the mission depends on dozens of critical decisions. Among the most important of these is the selection of the aiming point —exactly where in space and time *Voyager* will pass Neptune.

In selecting an aiming point, mission designers must choose a path that puts *Voyager*'s scientific payload in the right place at the right time, so the instruments will be able to take as much data as possible while *Voyager* is near Neptune and Triton.

Like its three Jovian relatives, Neptune has a lot to offer inquiring humans, from the geology of its bizarre moon Triton to unusual partial arcs of ring material. Although Earth-based charge-coupled device (CCD) images suggest there are features in Neptune's atmosphere, *Voyager*'s experience at Uranus offers little encouragement for much interesting detail in the frigid atmosphere. Cloud patterns will probably be obscured by a Uranuslike high-altitude haze.

As if to compensate the *Voyager* team for the probable lack of atmospheric detail on the planet, Neptune's partial ring arcs provide tantalizing targets for *Voyager*'s sensors — and may turn out to hold big surprises for planetary astronomers. In addition, Neptune is only half the excitement. Neptune's major satellite Triton should offer astronomers clear views of an exotic surface. Although Triton has an atmosphere, the atmosphere is probably sufficiently thin that surface features — perhaps even lakes or oceans of liquid nitrogen — can be imaged by *Voyager*'s cameras.

So where should we aim? From a purely scientific point of view the ideal *Voyager* trajectory plunges deep into Neptune's probable magnetosphere, probes the atmosphere, swings close to Triton, and provides a variety of perspectives on Neptune's ring system. But from a practical point of view the chosen flight path must not place the spacecraft in danger.

And there *are* dangers. Speeding past Neptune at 27 kilometers per second, *Voyager* would be disabled if it slammed into a ring particle the size of a grain of sand. Or atmospheric drag could set *Voyager* tumbling out of control as it skims close to the planet. Intense radiation could delay the spacecraft clock, and *Voyager* might helplessly fly past Neptune.

For absolute safety the *Voyager* scientists could opt for a trajectory that gives Neptune wide berth. By steering clear of the planet they could guarantee that *Voyager* would not encounter a stray ring particle, lose attitude control in the upper reaches of Neptune's atmosphere, or suffer possible timing errors because of a radiation-impaired clock.

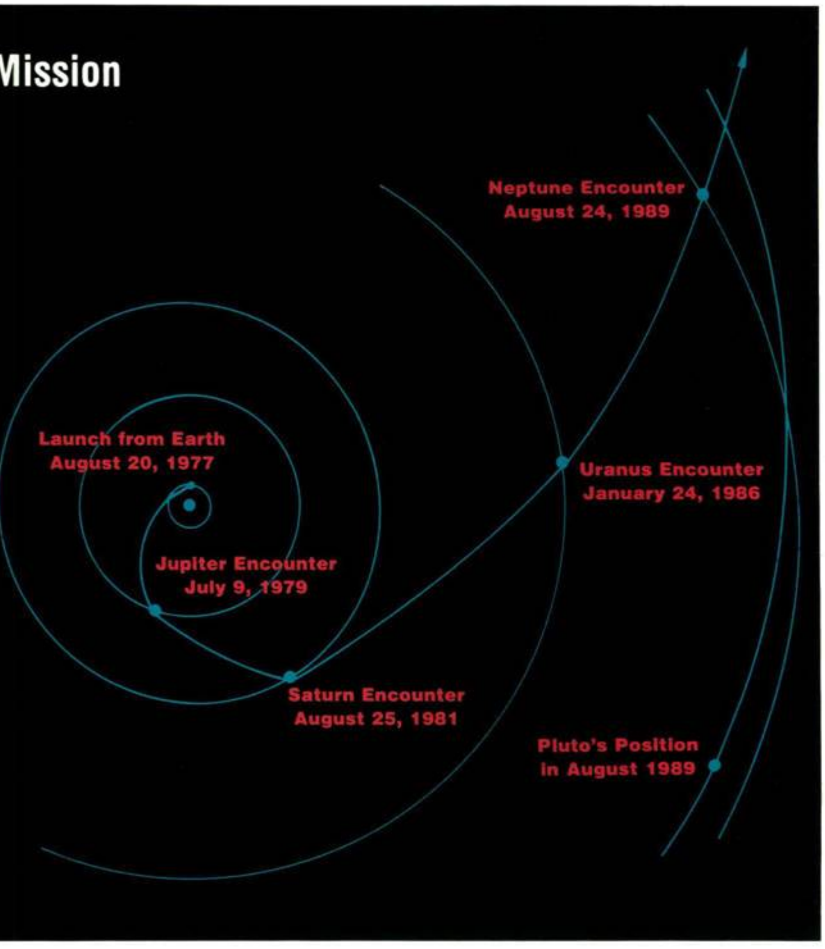
But the safe approach provides too few opportunities to make scientific measurements. Imaging resolution would suffer. We would learn little or nothing about the Neptunian ring system. Triton would appear small and fuzzy. If *Voyager* did not carry its charged-particle sensors into Neptune's magnetosphere, we would learn nothing about a region teeming with subatomic particles

## *Voyager*'s Gravity-Assisted Mission

***Voyager 2* could not have reached Neptune without the help of the three other planets it has encountered. Because the spacecraft approached each planet from behind, the mission designers ensured that the spacecraft would gain energy at each encounter by using the gravitational field of each planet to alter its path and direct it toward its next target.**

**Because a gravity-assist swingby to Pluto is not possible, mission designers are free to choose the best possible aiming point and corresponding flight path through the Neptune system.**

***Voyager 2*'s mission will not end in 1989, however. The probes will continue to sample the invisible sea of particles as the spacecraft leaves our solar system, searching for changes that indicate the probes have reached true interstellar space. If its subsystems continue to function *Voyager 2* will radio news to Earth well into the first years of the twenty-first century.**



trapped in Neptune's rotating magnetic field, a region that provides scientific insights about the deep interior of the planet itself as well as the space around it. If we played it "better safe than sorry," we would regret we had learned so little about Neptune.

On the other hand, the daredevils among the *Voyager* scientists might advocate a trajectory through the fringes of Neptune's upper atmosphere, which would grab just enough drag to remain within the control authority of the spacecraft's tiny thrusters, followed by buzzing Triton by a few thousand kilometers. The thrill-seeker's approach could produce a rich harvest of scientific results — or end the flight of *Voyager* before it completes its mission.

The dilemma is obvious.

The solution is equally obvious: *Voyager* must fly close enough to Neptune to return new scientific data but not so close the spacecraft is endangered. It all sounds so easy.

But fundamental uncertainties remain. *Voyager* is an explorer, and Neptune is new territory. Not only do we not understand all the problems we think we might encounter, but we do not know all the dangers Neptune might pose. After all, how well can Earth-based planet modelers estimate the density of Neptune's thermosphere from 4.5 billion kilometers away? How can field and particle experts estimate trapped radiation levels when no one knows whether the planet has a magnetic field or not? For that matter, how can astronomers predict where ring material will be when we're not even sure what sort of rings we'll find?

### The Original Aiming Point

By 1980 the trajectory design experts had run their computer programs and generated an aiming-point diagram for the Neptune system. Like a giant dart board, the aiming-point diagram showed zones of high scientific value: high-point "targets" for the "archers" on the navigation team to hit. Targets ranged from very close to as distant as 350,000 kilometers from Neptune. Many aiming points on the diagram were of interest, but only one could be chosen. The question of the day was: Which aiming point would achieve optimum science return from the flyby?

Scientists on the *Voyager* Science Steering Group, which met to weigh science issues and select the best trajectory for science, consistently preferred very close encounters with both Neptune and Triton. Close encounters provide the best photographic and optical sensor resolutions, the best opportunity to measure gravitational and magnetic field properties, and the best chance to detect energetic particles and plasmas. Passage of *Voyager*'s radio beam through an atmosphere or through ring media, as the materials alter the signal strength and phase, would allow the Radio Science Team to deduce the materials' key properties. Observing an occultation of the Sun by an atmosphere allows the Ultraviolet Spectrometer Team to measure the presence of many elements and chemical compounds.

Ideally the scientists wanted an occultation of both the Sun and Earth as seen from the spacecraft to follow each encounter. Finally, as frosting on the cake, they wanted a flight path that would place one or more stars behind Neptune's ring arcs during the near-encounter flyby at a time when the photopolarimeter instrument would be available to observe the star.

To achieve close flybys of both Neptune and Triton, an aiming point called the "inner Triton locus" looked best. This aiming point required a close pass over the north polar regions of Neptune to gain sufficient gravitational deflection for an encounter with Triton five hours later. Even though rings had not been detected in 1980, the scientists decided to play it safe by recommending that the spacecraft cross the equatorial plane — where possible rings might be lurking — at least 1.3 Neptune radii from the planet. This led to a Triton flyby distance of 44,000 kilometers. The chosen Neptune arrival time was 23.2 hours Greenwich mean time (GMT) on August 24, 1989.

But the *Voyager* Imaging Team kept pushing for a much closer Triton flyby, and the Radio Science Team wanted a later arrival time. Consequently at the September 1985 meeting of the *Voyager* Science Steering Group the recommended Triton flyby distance was reduced to 10,000 kilometers and the Neptune arrival time pushed back to 4.0 hours GMT on August 25. The former allowed steadier target motion for better pictures on approach to Triton, and the latter timed the radio signal occultations by Neptune and Triton so the spacecraft would be high above the horizon for the tracking antennas of the Deep Space Network, the Japanese antenna at Usuda, and the Australian Parkes radio telescope.

***Voyager* is an explorer, and Neptune is new territory.**

A new nominal trajectory was computed. The spacecraft would pass a mere 3,400 kilometers above the atmosphere of Neptune at the time of closest approach to the gas giant. Everyone liked the new trajectory. With navigation errors of a few hundred kilometers at most, *Voyager* appeared safe from any possible harm by Neptune's upper atmosphere or recently discovered ring arc region.

### Nature Raises the Ante

Then late in 1985 came four surprises, all of the Murphy's Law type, that jolted mission designers into a frenzy. Scientists responsible for providing the mission designers with the best possible estimates of Neptune's size and mass (the "physical constant estimators") announced their best new models revealed that Neptune's mass was 1.5 percent smaller than previously estimated and that the planet's radius was nearly 1,000 kilometers larger. The angle of tilt of Neptune's pole, they decided, was 4 degrees larger than they thought it had been before. Furthermore, a new and improved ephemeris of Triton placed the satellite nearly 8,000 kilometers south of where it had been before.

Using the powerful computers at the Jet Propulsion Lab, trajectory expert Bob Cesarone "searched in" a new nominal flight path. He held to the targeting objective of passing Triton at a distance of only 10,000 kilometers. To everyone's surprise the new trajectory was scheduled —on paper — to pass *inside* the outermost ring arc region just forty-five minutes before *Voyager* swung above Neptune's northern pole only 1,250 kilometers above the atmosphere.

This risky flight path triggered the *Voyager* Mission Planning Office to begin three studies. These would ultimately lead to moving the aiming point farther from Neptune and as a result farther from Triton as well.

The Mission Planning Office strategy was three-pronged. While environmental expert Neil Divine developed new models for Neptune's upper atmosphere, rings, and radiation levels for use in spacecraft risk calculations, Ellis Miner and Peter Doms of the Flight Science Office would organize a series of science meetings to evaluate aiming points for best scientific return.

And the third prong? Jim Gerschultz of the Mission Planning Office would meet regularly with the physical constant estimators (the people who had made Neptune so much bigger and lighter) to reduce the chance of any more surprises.

Whenever risk to a spacecraft is a possibility, even a slim one, mission planners try to ensure that calculations are made in a conservative manner. Divine was asked to develop "upper limit" environmental models, that is, models in which there would be no more than a 5 percent chance that the real world would be worse. For Neptune's upper atmosphere this calculation would lead to the greatest reasonable value of atmospheric density for a given flyby distance, thereby giving the highest reasonable estimate of the drag forces on the spacecraft.

**The risk assessors reflected long and hard before giving the green light to a close Neptune flyby.**

Based on the failure of the *International Ultraviolet Explorer* satellite to detect Neptune from its ultraviolet signature and assuming that electroglow generates Lyman-alpha radiation and is related to the temperature, Divine was advised to assume a highest temperature of 500 kelvins for Neptune's upper atmosphere. He then provided a density model to Robert Frampton of the Mission Planning Office for the calculation of safe spacecraft flyby distances. Frampton wanted to avoid not only the drag-induced problems such as loss of attitude control but a variety of other possible problems ranging from high-voltage arcing to the remote possibility the spacecraft thermal blankets could tear. *Voyager* had not been designed for atmospheric entry!

The risk calculations showed that the danger of high voltage in the spacecraft through the thin gas arcing was the greatest concern and blanket tearing was the least. To avoid high-voltage arcing, *Voyager* must pass no closer than 27,300 kilometers from the center of Neptune (some 2,550 kilometers above the one-microbar atmospheric pressure level and 3,100 kilometers above the cloud deck), pushing the Triton flyby distance out to 23,000 kilometers.

Because of the tremendous gravitational deflection of the close pass over Neptune, the effect on the flight path and therefore on the Triton flyby distance is dramatic. For each kilometer the Neptune closest approach distance increases, that of Triton increases by nearly ten kilometers!

This "leverage" effect has important consequences, because some atmospheric scientists believe the electroglow-ultraviolet argument is not valid. If Neptune's upper atmosphere is as hot as 1,000 kelvins, then the safe Neptune flyby distance must be moved out another 1,350 kilometers, forcing the Triton flyby distance out to 36,500 kilometers.

### Neptune's Unusual Rings

Jupiter has rings, Saturn has rings, and Uranus has rings. What about Neptune? The best astronomers can say is that Neptune seems to have rings, but they aren't complete. What we know of Neptune's rings comes from ground-based occultations of stars, when a ring reveals its presence by momentarily blocking the light of the star.

From the observations Neptune appears to be surrounded by at least three near-circular rings, orbiting 41,000 to 67,000 kilometers from the center of Neptune. Neptune's rings aren't like most other rings we know. A recent analysis of stellar occultation data by Philip Nicholson of Cornell, William Hubbard of the University of Arizona, and other observers shows the ring material does not fill entire rings but only arcs of the rings.

The partial ring arcs are less than 20 kilometers wide, so the random chance of a spacecraft collision with a ring arc is well under 1 percent. Even if the *Voyager* navigators *tried* to hit one of these arcs, the chances of succeeding would not exceed 10 percent. The real concern is that a diffuse sheet of unseen particles may span a region thousands of kilometers in radial width.

If the source of these diffuse particles is the outermost arc, then *Voyager* would find safe passage outside this arc, because drag from the slower plasma that rotates with the planet would cause the unseen ring particles to experience orbital decay and migrate inward towards Neptune.

It seems simple enough to fly *Voyager* through Neptune's equatorial plane just outside the 67,000-kilometer ring arc region. Unfortunately, because Neptune is so far away, planetary astronomers cannot be sure of the exact location of the 67,000-kilometer ring. Assuming an uncertainty of 4,000 kilometers in the outer ring arc's distance from the center of Neptune and an orientation of the equatorial plane based upon the heaviest probable Triton, the Neptune closest approach distance must be more than 28,950 kilometers from the center of Neptune, which pushes the Triton flyby distance farther out to 38,500 kilometers.

But what if there are more distant ring material sources, such as one or more small satellites, out beyond the most distant ring arc currently detected? After all, at an impact speed of 27 kilometers per second (60,000 miles per hour), particles as small as 100 microns in diameter (0.004 inches, the size of a fine grain of sugar) could still inflict serious damage. At this point, calculating the risk to the mission becomes very involved and requires numerous assumptions about the number densities of ring particles and the vulnerability of the spacecraft to impacts of various sizes.

Neil Divine and the Mission Planning Office's Rex Ridenoure have made these complex calculations and find the probability of collision with a ring particle ranges from nil to almost certainty, depending on which assumptions are used. All in all, however, the scientists on the *Voyager* project believe the region beyond the outermost ring arc is safe, though the element of uncertainty that remains is certain to heighten the suspense as the world follows the robot explorer during its high-speed dash through the

Neptune system.

And, as an extra precaution, if the long-exposure images of Neptune's rings made during *Voyager*'s approach to Neptune reveal potentially dangerous ring material regions, project officials may ask the navigators to move the aiming point outward for a safer passage.

### Neptune's Unknown Radiation

It is easy to imagine the concerns that arise when a spacecraft flies through the fringes of a planetary atmosphere or a region infested with ring particles. But trapped radiation, largely in the form of high-energy electrons racing at near-light speeds, can be every bit as dangerous. Furthermore, radiation is difficult for the risk estimators to handle, because no measurements have ever been made of Neptune's trapped radiation. Because of the large numbers of energetic particles at Jupiter, Saturn, and Uranus, planetary scientists expect to find Neptune likewise surrounded by a vast region of similar particles trapped within a rotating magnetosphere.

We call the rate at which energetic electrons cross a given area the "flux" of particles. We might, for example, measure a flux of $10^6$ high-energy electrons per square centimeter per second. The total number of particles that cross the area at the end of, say, an hour, is the "fluence." At the end of an hour the flux mentioned above would produce a fluence of $3.6 \times 10^9$ high-energy electrons per square centimeter.

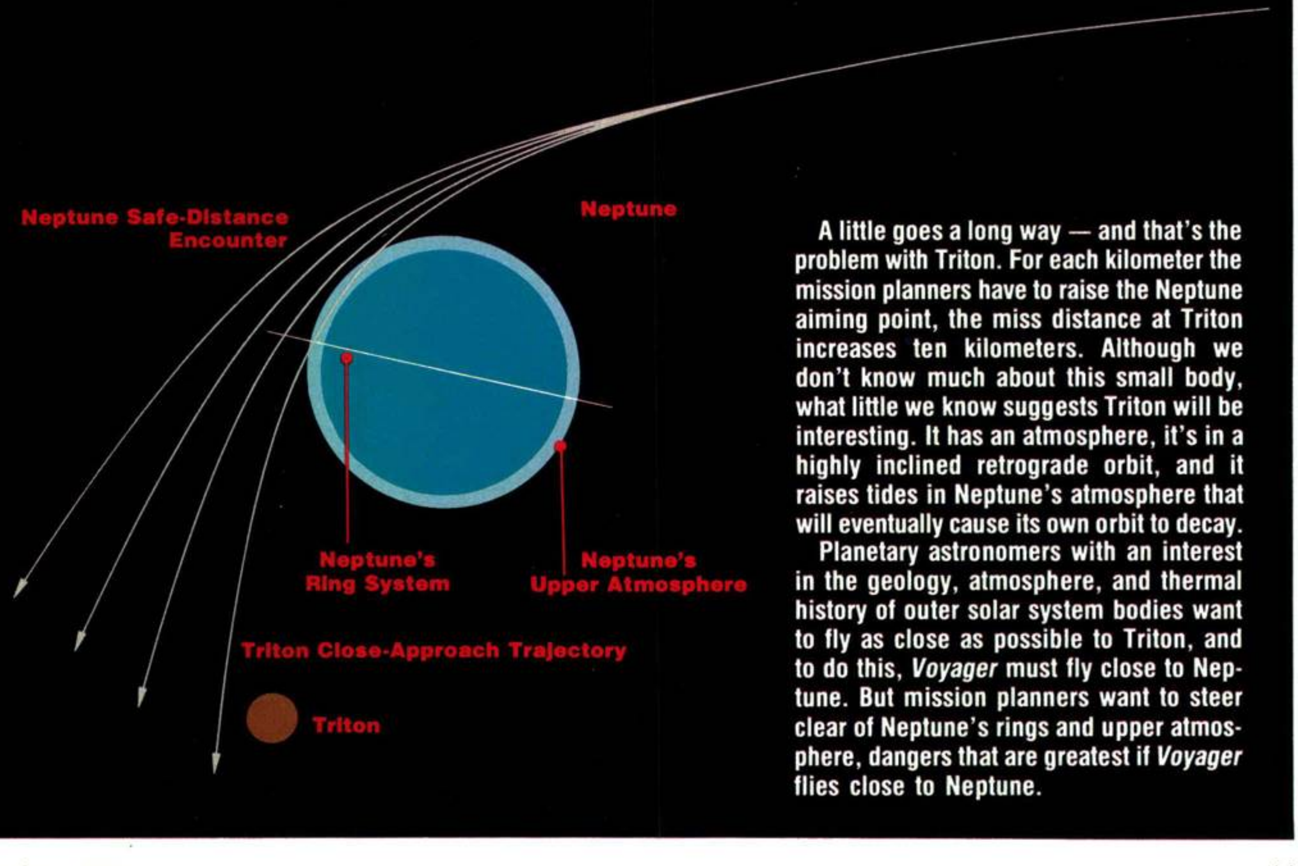
Flux and fluence affect spacecraft components in different ways. High flux tends to cause temporary disturbances but generally does not cause permanent damage, whereas high fluence, akin to a total radiation dose, can lead to permanent loss of function.

In January 1987 Divine and project scientist Edward Stone organized a meeting for planetary trapped-radiation experts to develop an upper limit model for electrons having energy levels at or in excess of 3 million electron volts — levels that could damage a spacecraft. Because *Voyager 1* survived Jupiter's intense radiation exposure of 53 million electrons per square centimeter per second peak flux and nearly 2 trillion electrons per square centimeter total fluence — albeit with some problems — the calculations of the Neptune radiation model were shown as fractions of the actual values experienced at Jupiter.

The risk assessors reflected long and hard before giving the green light to a close Neptune flyby. The upper-limit radiation model for a close flyby over the north polar region of Neptune resulted in a peak flux over half that encountered by *Voyager 1* at Jupiter. But because Neptune's magnetosphere is likely to be smaller than Jupiter's and because *Voyager* will pass through it more rapidly, the total fluence should be roughly thirty times smaller. Also, the time spent near peak flux would be only one hour rather than the several hours of high flux *Voyager 1* endured in passing through the vast Jovian magnetosphere.

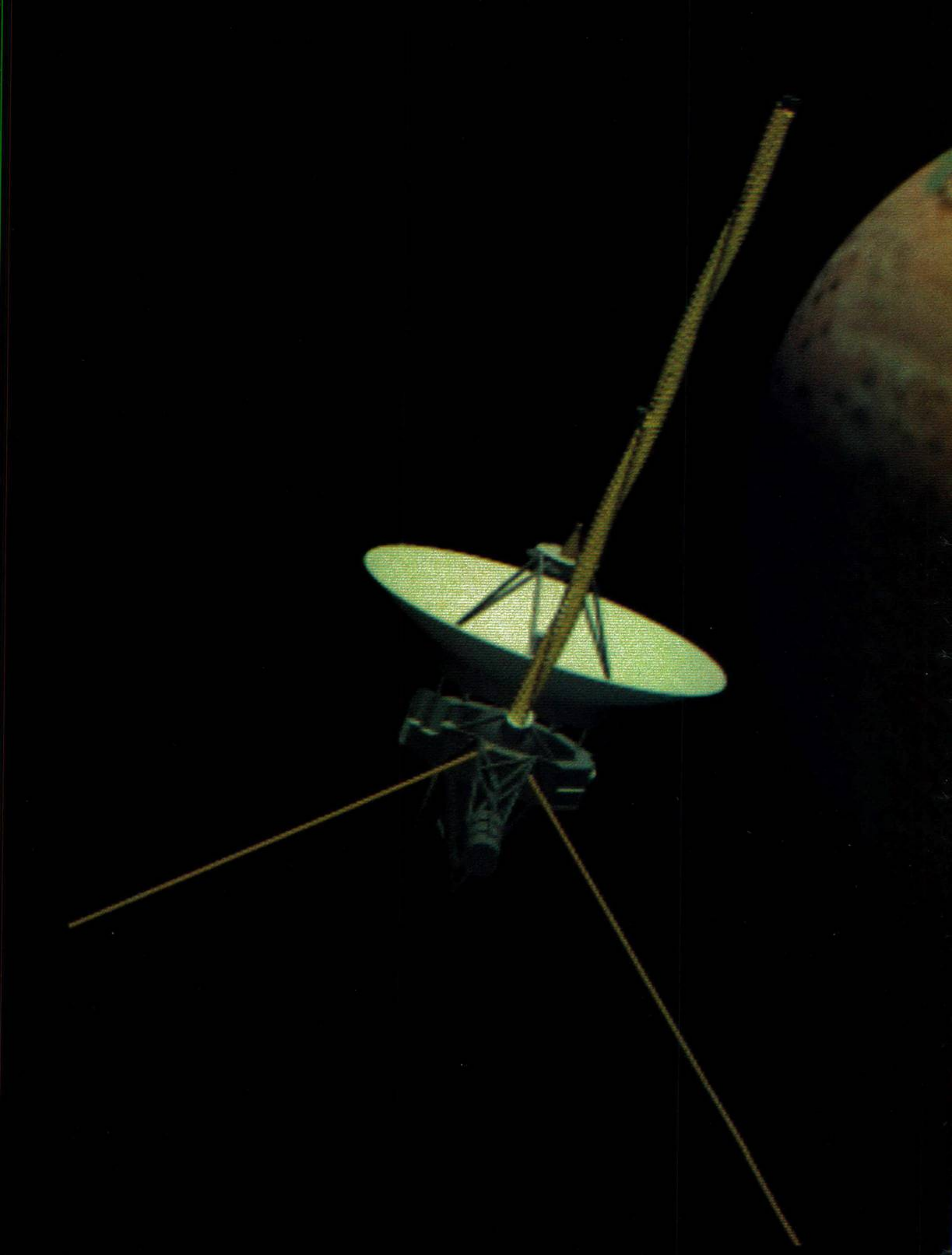
To be on the safe side, however, the *Voyager* mission plan calls for precautionary measures in the Neptune near-encounter sequence. At Jupiter the high radiation flux led to increased background noise for some of the scientific sensors and extended periods of degraded performance in a few cases. Though the degradation of the instruments at Jupiter was the result of extremely high fluence and therefore not a serious concern at Neptune, the high radiation levels also caused timing errors in *Voy-*

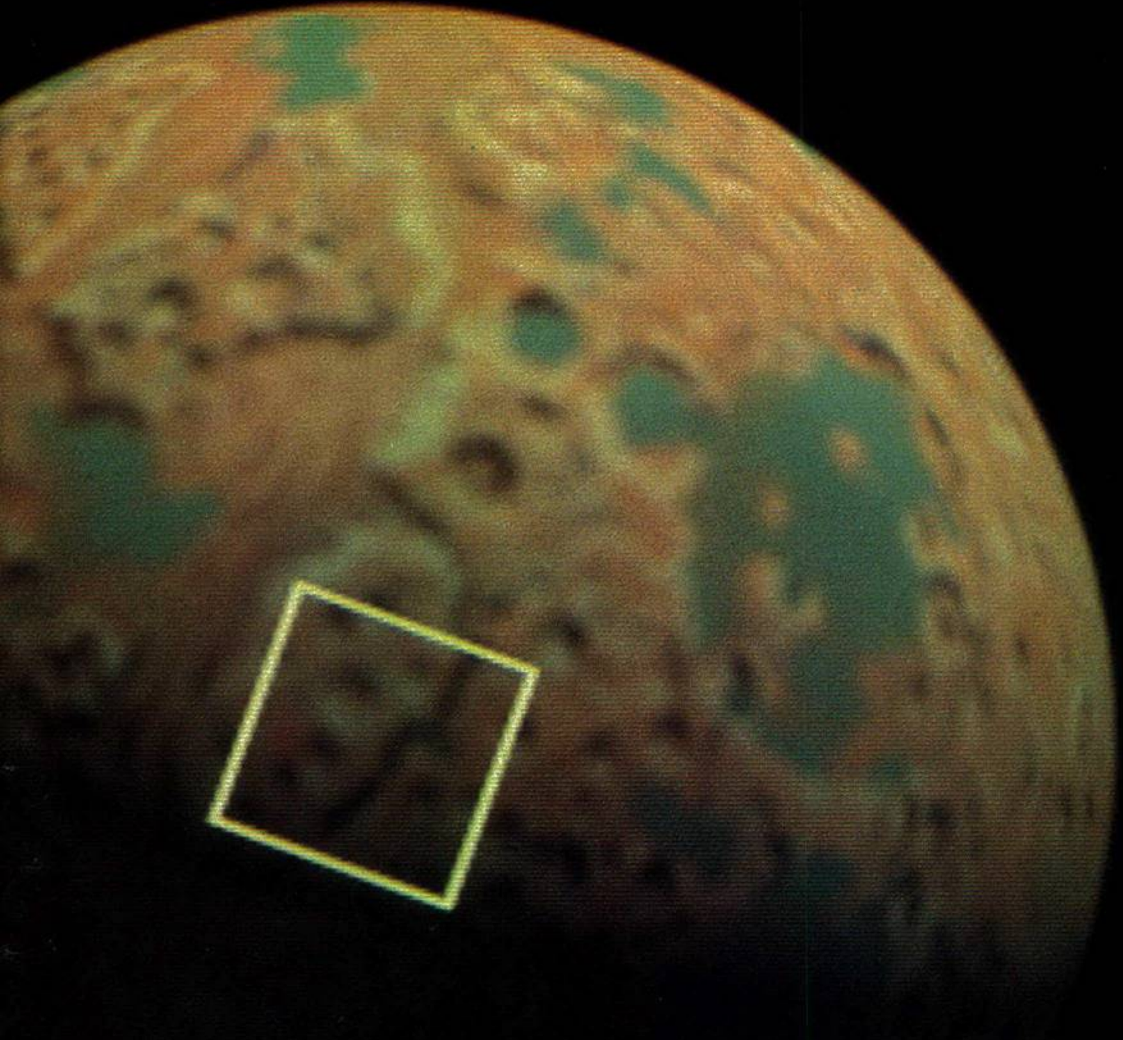
## Gravitational Leverage: The Triton Dilemma


Neptune Safe-Distance Encounter
Neptune
Neptune's Ring System
Neptune's Upper Atmosphere
Triton Close-Approach Trajectory
Triton

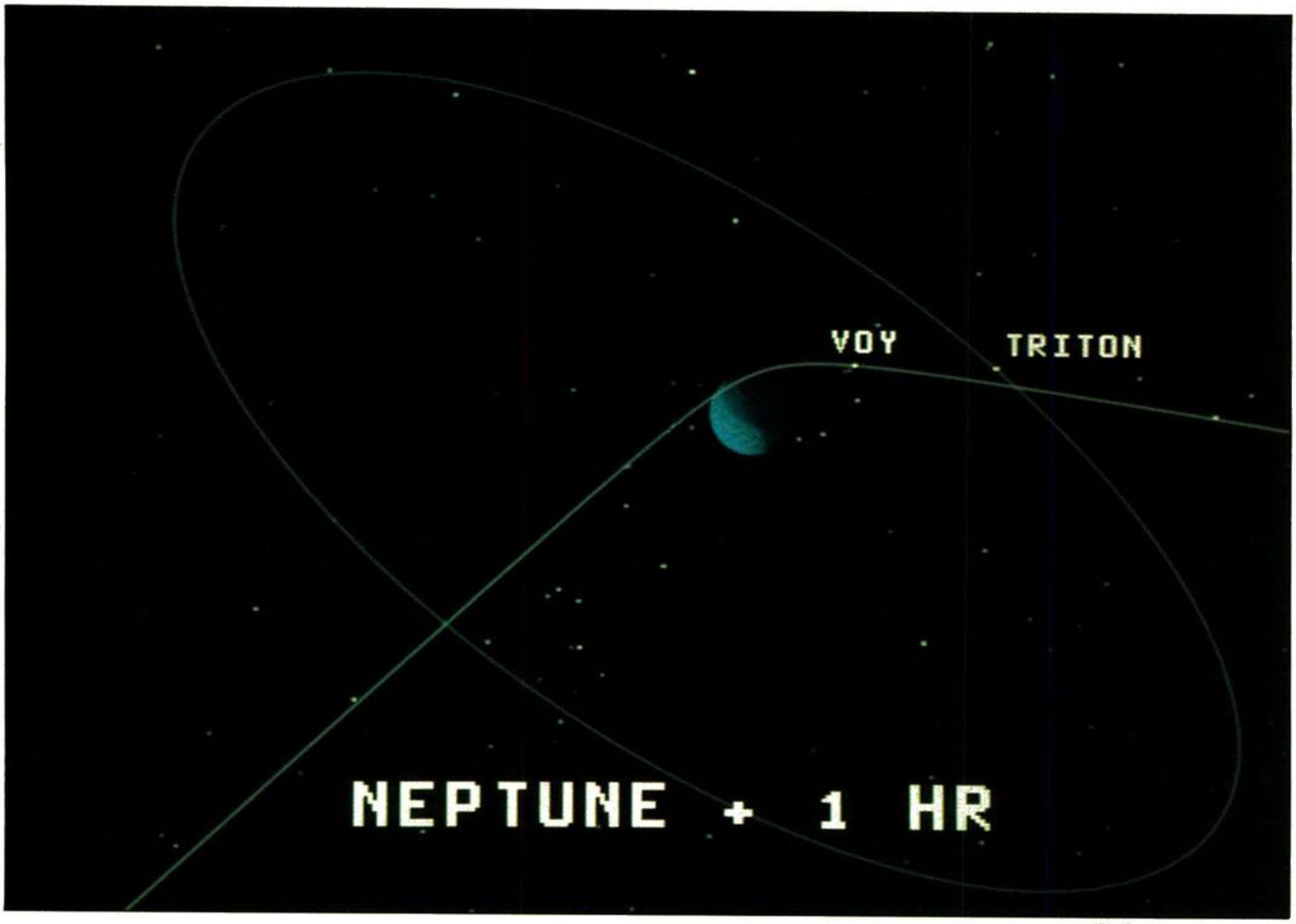
**A little goes a long way — and that's the problem with Triton. For each kilometer the mission planners have to raise the Neptune aiming point, the miss distance at Triton increases ten kilometers. Although we don't know much about this small body, what little we know suggests Triton will be interesting. It has an atmosphere, it's in a highly inclined retrograde orbit, and it raises tides in Neptune's atmosphere that will eventually cause its own orbit to decay.**

**Planetary astronomers with an interest in the geology, atmosphere, and thermal history of outer solar system bodies want to fly as close as possible to Triton, and to do this, *Voyager* must fly close to Neptune. But mission planners want to steer clear of Neptune's rings and upper atmosphere, dangers that are greatest if *Voyager* flies close to Neptune.**



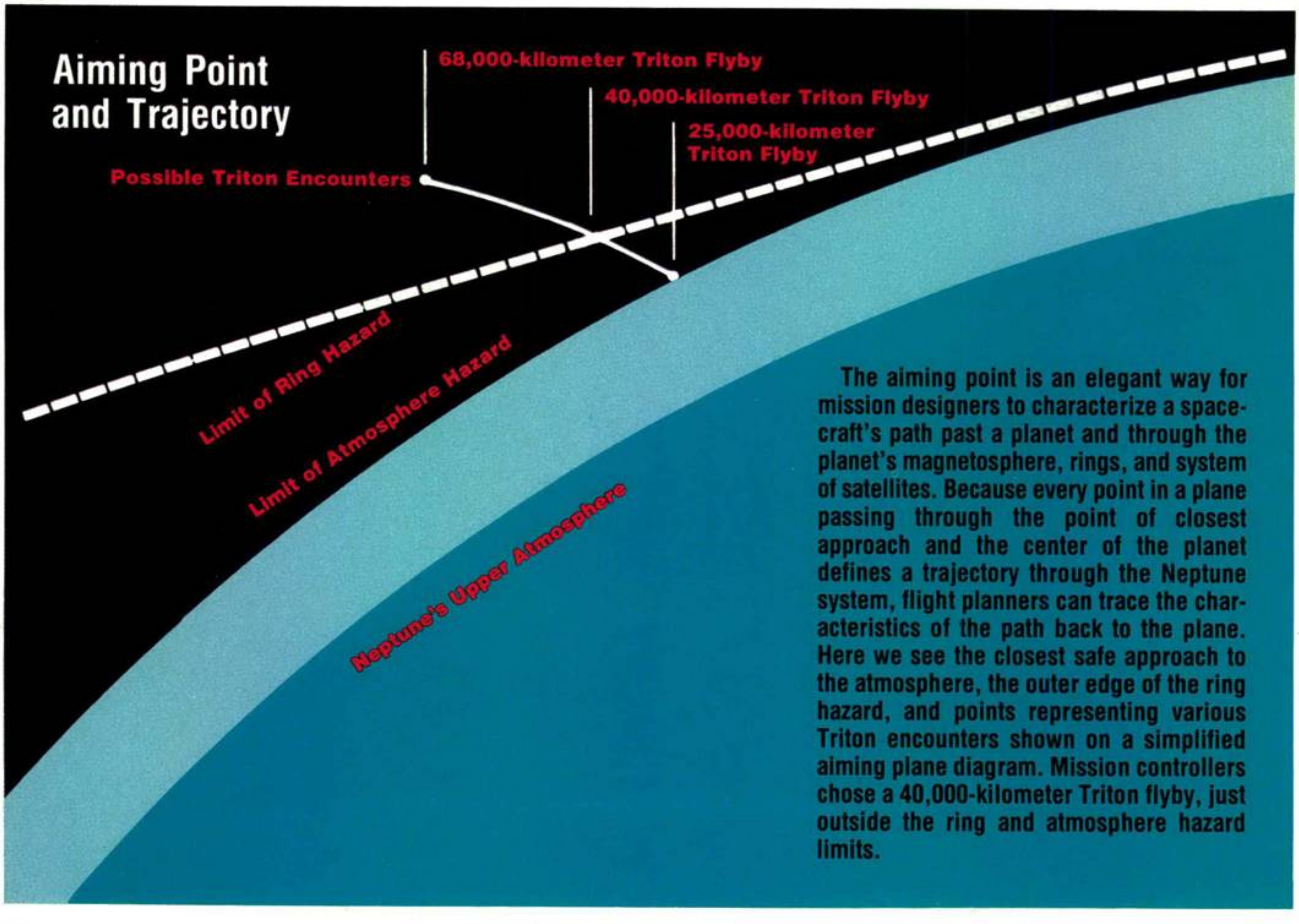


During *Voyager*'s encounter with Triton, the spacecraft's sensors and cameras will scan this mysterious world and relay pictures and data back to Earth. Image courtesy of the JPL Computer Graphics Lab.


VOY
TRITON
NEPTUNE + 1 HR

JPL Computer Graphics Lab

## Aiming Point and Trajectory


68,000-kilometer Triton Flyby
40,000-kilometer Triton Flyby
25,000-kilometer Triton Flyby
Possible Triton Encounters
Limit of Ring Hazard
Limit of Atmosphere Hazard
Neptune's Upper Atmosphere

The aiming point is an elegant way for mission designers to characterize a spacecraft's path past a planet and through the planet's magnetosphere, rings, and system of satellites. Because every point in a plane passing through the point of closest approach and the center of the planet defines a trajectory through the Neptune system, flight planners can trace the characteristics of the path back to the plane. Here we see the closest safe approach to the atmosphere, the outer edge of the ring hazard, and points representing various Triton encounters shown on a simplified aiming plane diagram. Mission controllers chose a 40,000-kilometer Triton flyby, just outside the ring and atmosphere hazard limits.

*ager*'s master electronic clock, which in turn caused the spacecraft to perform its duties too late. To avoid this, the clock will be checked and if necessary corrected by special commands sequenced during the Neptune flyby.

*Voyager* will be the only spacecraft to visit Neptune during the twentieth century and possibly well into the twenty-first. Selecting the best trajectory for this one and only encounter is all the more crucial because there will be no second chance.

### Trade-Offs for Triton

At first blush, selecting an aiming point seems simple: fly just as close as you can fly safely, presumably just outside the outermost ring-arc region. While this is essentially correct, two important considerations can't be ignored. Navigation errors are more troublesome in a close flyby because the effects of an error are greater. Furthermore, during a close flyby, key events occur too rapidly. There is not enough time for the spacecraft to squeeze in all the observations the scientists want to make.

So the mission design teams examined a variety of trajectories with Triton flyby distances from 20,000 to 70,000 kilometers. The scientists who favored a close flyby stressed better Triton imaging resolution, a better chance of obtaining both Sun and Earth occultations by Triton, and sufficient radio signal bending by Neptune's atmosphere to obtain measurements below the methane cloud deck.

But more distant flybys gave the spacecraft more time to move its cameras and transmit images to Earth and made tracking the limb of the planet during the Earth-occultation period easier for the spacecraft. The speed of events promised not to overload *Voyager*'s rather limited ability to carry out its assigned observing tasks.

After a great deal of analysis and debate among the Science Steering Group members, two recommendations were made. The Imaging Science Team requested a flyby 25,000 kilometers from Triton and the Radio Science Team requested a 55,000-kilometer Triton flyby, primarily to insure that *Voyager* would be able to point its antenna accurately toward the limb of Neptune during the radio occultation.

The leader of the Science Steering Group, Edward Stone, decided on a compromise Triton flyby distance of 40,000 kilometers. This choice favors the Triton dual-occultation experiments and ensures that *Voyager* will pass outside of the outermost known ring arc region during its inbound crossing of Neptune's equatorial plane.

The *Voyager* Project had chosen a new aiming point. Though four times farther out than the 10,000-kilometer Triton flyby recommended in September 1985, the new aiming point chosen was, ironically, close to the Triton flyby distance that had been initially selected in August 1980.

### Capability for Change

Flying a trajectory 40,000 kilometers from Triton gives not only an exciting mission from a scientific point of view but achieves what everyone hopes is the best balance between mission return and mission risk. Best of all, if *Voyager* scientists turn up any new information about Neptune's environment that suggests a different aiming point, *Voyager* carries sufficient reserves of propellant to alter its trajectory as late as a week prior to encounter.

In the absence of new data about the Neptune environment the capability for change is still a dynamic topic with Navigation Team Chief Donald Gray and his targeting team. They constantly assess and reassess the value of different navigation strategies to meet the mission and science objectives.

What might happen? One scenario involves Triton. Current estimates of Triton's diameter range from as little as 2,000 kilometers to as large as 6,000 kilometers. During approach to Neptune, *Voyager* images will reveal the actual size of Triton. To optimize the science return from the mission, the spacecraft navigators might make slight trajectory adjustments shortly before the encounter.

Living up to *Voyager*'s achievements at Jupiter, Saturn, and Uranus is a challenge for the planners of the Neptune encounter. But the Neptune and Triton encounters offer the promise of an exciting finale for humanity's epic first visits to the Jovian giant planets. Will we see lakes of liquid nitrogen on Triton? Might Neptune itself show interesting cloud features? Will we discover more moons and rings orbiting the planet? Maybe, but one thing is clear: The remote encounter should be worth a few surprises for an Earth-bound audience of space fans, providing new images and fresh data for the minds of humans striving to understand their small corner of the universe

**During a close flyby, key events occur too rapidly.**

***Voyager*'s narrow-angle camera captured this image of Neptune and Triton from a range of 1.373 billion kilometers. Taken in January 1987, images like this help *Voyager*'s human controllers navigate the spacecraft by showing the target world against a background of stars. Neptune appears smeared slightly in this 5.7-second exposure. This November the spacecraft will take another set of navigation images. JPL photo.**

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*Charles E. Kohlhase is the Mission Design Manager for the* Voyager *project at Caltech's Jet Propulsion Laboratory. In addition to magazine articles (see "On Course for Neptune," November 1986), Kohlhase has written adventure software (*Wilderness: A Survival Adventure [Spectrum Holobyte]*), participated in the creation of special effects sequences for Carl Sagan's television series* Cosmos, *and is currently writing his first novel. Kohlhase received the NASA Outstanding Leadership Medal for the design of the highly successful* Voyager *mission.*

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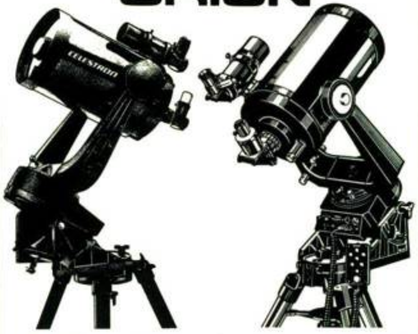

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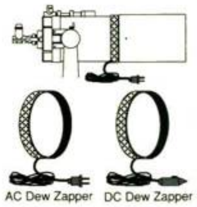

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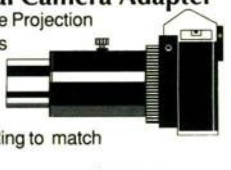

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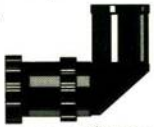

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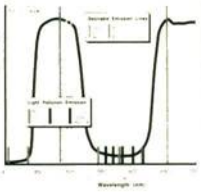

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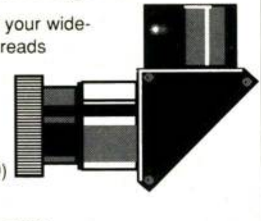

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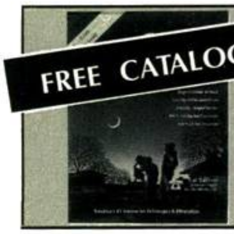

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# Explosions in the Solar Atmosphere

*Releasing the energy of a billion megaton bombs within a few minutes, solar flares are the most violent disturbances on the Sun.*

by A. Gordon Emslie

To a casual observer the Sun is constant. But the atmosphere of our star is often wracked by tremendous explosions — called solar flares — that release prodigious amounts of energy and accelerate billions of tons of material at speeds up to a million miles per hour. Astronomers are now studying these complex explosions with instruments ranging from radio telescope arrays to gamma-ray spectrometers to learn exactly how solar flares work.

The first recorded solar flare occurred on September 1, 1859. English astronomers Richard C. Carrington and R. Hodgson were observing sunspots that day when they independently witnessed the event. The flare lasted only a few tens of seconds and, as the astronomers described in back-to-back papers in the *Monthly Notices of the Royal Astronomical Society*, appeared as "two patches of intensely bright and white light" among an unusually large group of sunspots. Carrington concluded that "the phenomenon took place at an elevation considerably above the general surface of the Sun."

A few minutes after the flare there was an intense disturbance in Earth's magnetic field, and early the next morning many observers reported a brilliant auroral display. Carrington noted the coincidence between these events and the flare but was reluctant to associate them, noting that "one swallow does not a summer make." Today we know that terrestrial magnetic disturbances *are* intimately related to solar flares and that flares affect Earth by, among other things, causing the aurorae, or northern lights, disrupting radio communications, and corroding long pipelines by inducing large electrical currents.

What Carrington and Hodgson saw was an extremely rare occurrence known as a white light flare — so named because the flare enhances the Sun's emission throughout the visible spectrum. In general, flares are best seen from Earth by observing the Sun through a filter transparent only to light from the hydrogen-alpha (H$\alpha$) spectral line located in the red-orange region of the spectrum.

## Activity on the Sun

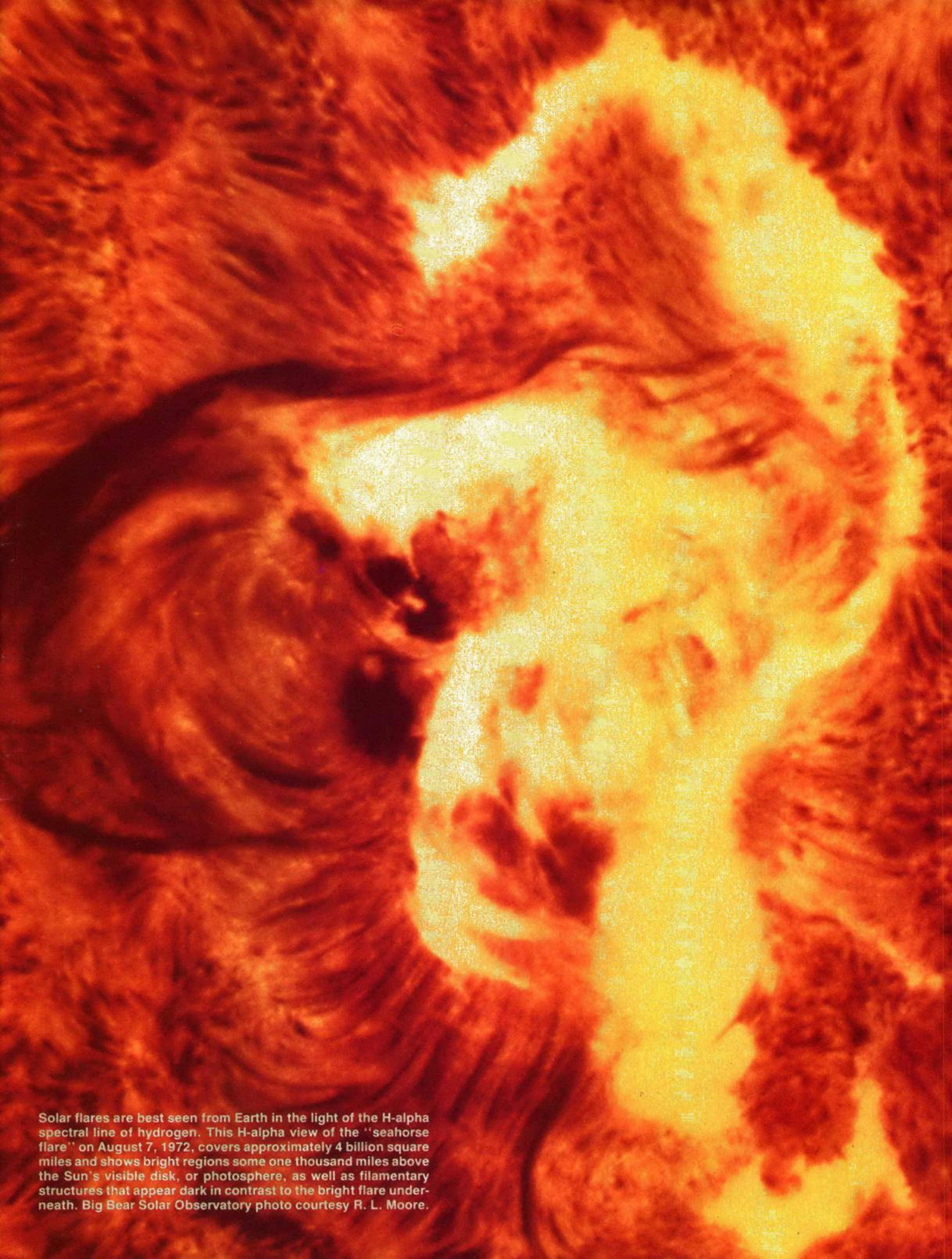
Like most stars and even planets, the Sun has a magnetic field. The average strength of this magnetic field is comparable to that of Earth's field. Unlike that of Earth's, however, the Sun's magnetic field is continuously changing: the strength of the field rises and falls with a period of approximately eleven years. As the field grows stronger, the Sun enters a phase of heightened activity that culminates once each cycle. The last period of peak activity, or solar maximum, occurred in 1980-81, and the next is predicted to occur sometime during 1991 or 1992.

During periods of high solar activity the size and number of active regions — areas on the Sun's surface where the magnetic field strength is enhanced — increase greatly. Frequently sunspots are embedded in these active regions, so the number of sunspots on the face of the Sun also increases during phases of high activity. These sunspots, which possess magnetic fields up to a thousand times stronger than normal, appear darker than the surrounding surface because they are 1,000 to 2,000 degrees Celsius cooler. (The German apothecary Heinrich Schwabe discovered the eleven-year solar activity cycle in 1843 by observing the variation in sunspot numbers with time.)

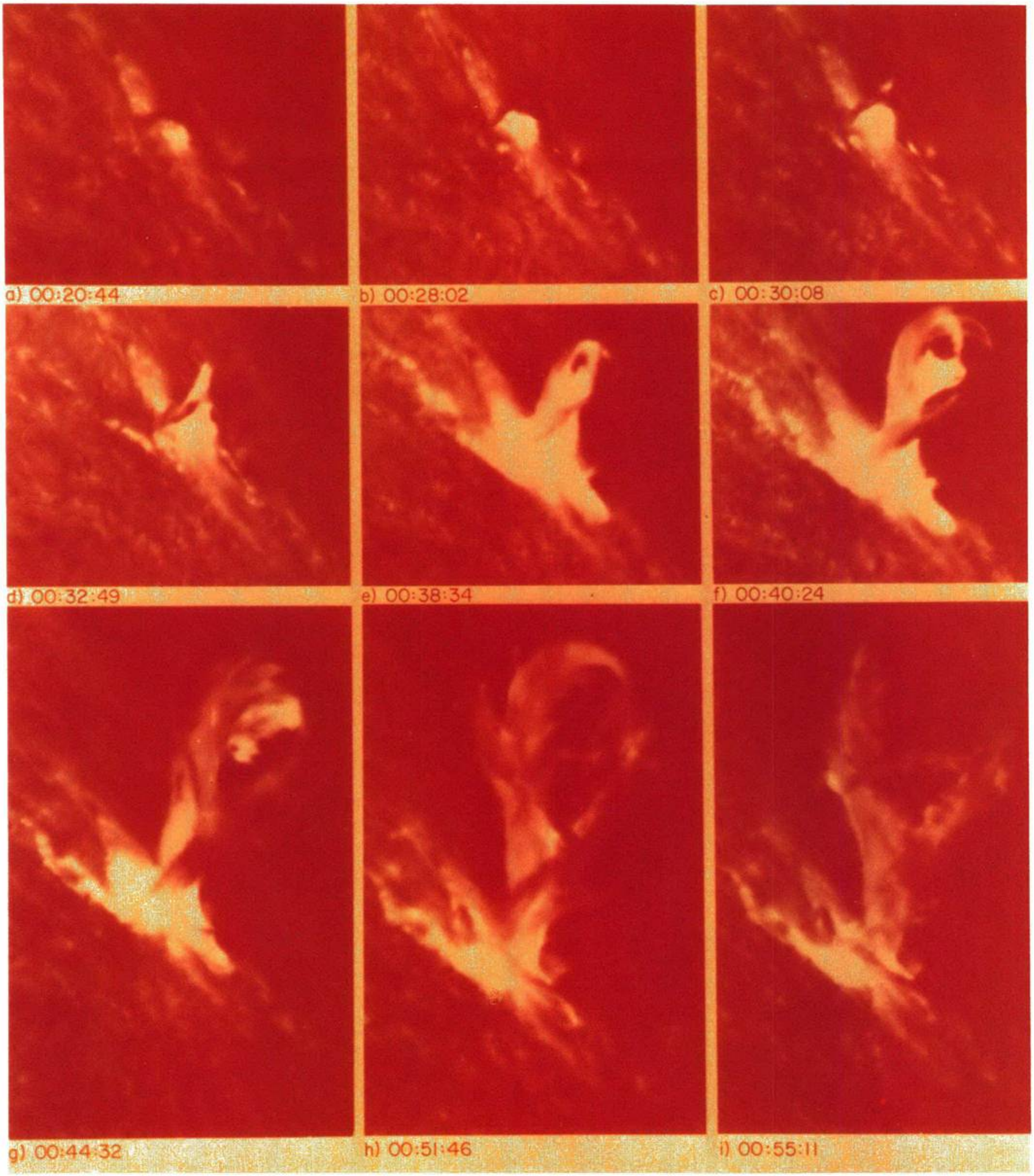
The driving force behind all solar activity is the outflow of energy from the Sun's interior. Every second the Sun converts 4 million tons of hydrogen into helium in nuclear reactions deep within its interior. The energy created in these reactions takes about a million years to make its way to the surface, where the energy is then radiated into space.

Solar activity manifests itself in many ways. This periodic activity, however, is confined mostly to the outer layers of the Sun; the nuclear furnaces in the Sun's core continue to produce power at a steady rate. The Sun is surrounded by a "skin" of million-degree gas called the corona. This tenuous gas can be seen in white light only during a total solar eclipse, when the Moon's disk obscures the blinding disk of the Sun. But x-ray telescopes in Earth orbit can view the corona at all times and show the corona as a bright shell surrounding a relatively cool, dim central star.

When solar activity is near minimum, dark gaps called coronal holes appear in the corona. Hot gases escaping from these regions constitute the solar wind, a stream of charged particles that flows throughout the solar system. When solar activity is near maximum, coronal holes are nearly absent, and instead we see prominences (relatively cool, dense regions of gas high above the solar limb), a large number of active regions and sunspots, and a dra-



Solar flares are best seen from Earth in the light of the H-alpha spectral line of hydrogen. This H-alpha view of the "seahorse flare" on August 7, 1972, covers approximately 4 billion square miles and shows bright regions some one thousand miles above the Sun's visible disk, or photosphere, as well as filamentary structures that appear dark in contrast to the bright flare underneath. Big Bear Solar Observatory photo courtesy R. L. Moore.



**A time sequence of the October 10, 1971, solar flare taken in H-alpha light shows that the dark filamentary structures associated with flares are ejected completely from the Sun. These structures may contain several billion tons of material and are ejected at speeds up to a million miles per hour. The times indicated are in hours, minutes, and seconds of universal time. Big Bear Solar Observatory photos courtesy R. L. Moore.**

matic rise in the number and size of solar flares. At peak solar activity the Sun can produce many flares each day. Although the energy released in a single flare — even a large one — is negligible compared to the total energy output of the Sun, flares are sufficiently localized that they show up as very bright regions in H-alpha, in ultraviolet light and x-rays, and even occasionally in white light.

## Solar Magnetism

The only energy source capable of producing the violent outbursts observed in solar flares is magnetic in nature, which ties in well with the increased frequency of flares during times of enhanced magnetic activity. As more and more regions of strong magnetic fields appear on the Sun, they are pressed together, building up magnetic energy in much the same way pressing two magnets together requires a greater energy input as they get closer to each other. At some point the system becomes unstable and, in the same way as the two pressed-together magnets will fly apart when suddenly released, all the stored energy is given off in a blinding flash of x-rays and ultraviolet radiation and in a burst of energetic electrons and protons. Solar astronomers do not yet understand the details of this process, but there is ample evidence supporting the basic scenario.

One popular model for explaining solar flares requires the released magnetic energy to accelerate huge numbers of particles. The thousands and sometimes millions of volts necessary to do this are believed to be produced by changes in the magnetic field strengths caused by interacting magnetic structures. (Although the ability of magnetic field changes to accelerate particles is a fundamental principle of the theory of electromagnetism developed by Scottish physicist James Clerk Maxwell in the nineteenth century, solar scientists do not fully understand how magnetic energy is converted to the energy of fast particles in solar flares.) Accelerated electrons stream through the solar atmosphere, heating the atmosphere through friction and producing x-rays by a process known as *bremsstrahlung* (from the German words *bremsen* meaning "to brake" and *Strahlung* meaning "radiation"). Accelerated protons collide with other nuclei, giving off gamma radiation when the excited nuclei decay radioactively.

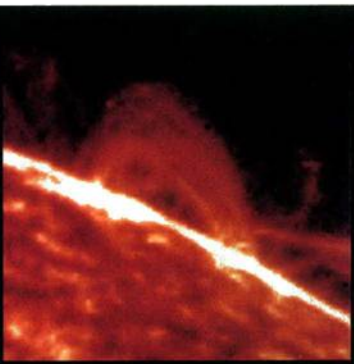
### The Observational Jackpot

Unfortunately most of the radiation produced during a solar flare never reaches Earth's surface. Our atmosphere effectively blocks all the high-energy radiation— ultraviolet, x-rays, and gamma rays — and lets pass only visible light, including H-alpha, as well as radio waves. To get a better understanding of the physical processes taking place within solar flares, astronomers need to study all the radiation flares emit.

One of the major steps in this direction was the observations made from the manned U.S. space station *Skylab*. During 1973 and 1974 three crews used *Skylab*'s telescopes to observe ultraviolet and x-radiation emanating from flares. But it was the *Solar Maximum Mission* (or *Solar Max*) satellite that revolutionized our knowledge of solar flares.

Launched into Earth orbit on February 14, 1980, *Solar Max* carried an array of seven instruments, six of which were designed specifically to study solar flares. Among these instruments was the first telescope designed to take pictures in high-energy x-rays and a gamma-ray spectrometer to measure the high-energy gamma radiation from nuclear reactions in flares. Also on board were telescopes to produce simultaneous images and spectra of low-energy x-rays and of ultraviolet radiation, a high-energy x-ray spectrometer, and a coronagraph to study the ejection of material into space. As part of an unprecedented international effort known as the Solar Maximum Year, several ground-based optical and radio telescopes made observations in coordination with *Solar Max* to provide relatively uninterrupted, around-the-clock observations of the Sun.

In November 1980 the guidance and pointing system of *Solar Max* failed. Unable to maintain an accurate fix on the Sun, the spacecraft remained in orbit with only the high-energy x-ray and gamma-ray spectrometers functioning (which did not require accurate pointing) until early 1984, when the spacecraft was repaired in orbit during a pioneering space shuttle mission. In the period between the failure of the pointing system and its subsequent repair, solar scientists began analyzing the enormous quantity of data gathered by the spacecraft.



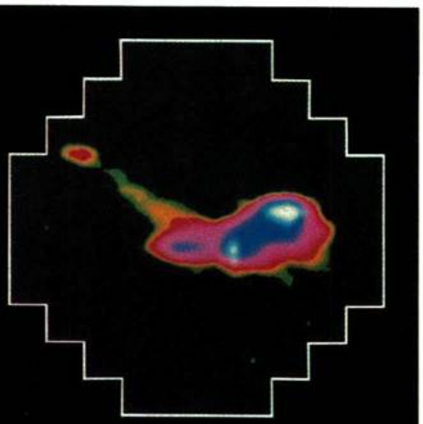
**An ultraviolet image taken by the *Solar Max* satellite reveals the structure of a magnetic loop after a flare on March 27, 1980. *Solar Maximum Mission* image courtesy A. Gordon Emslie.**

One of the more startling findings was that the highest energy x-rays, called hard x-rays, (produced by electrons accelerated by tens of thousands of volts), are generated at the same time as the gamma rays (produced by nuclear reactions involving protons accelerated by many millions of volts). Until *Solar Max*, solar astronomers thought the protons were accelerated in a separate, second stage of the flare. But the close timing of the x-ray and gamma-ray bursts proved this wrong: the electrons and protons are accelerated simultaneously within seconds after the start of the flare. Solar physicists, who had struggled for years with the problem of how the electrons are rapidly accelerated, were now faced with twice the problem they had before.

Observations of high-energy neutrons compounded the problem. The gamma-ray spectrometer on *Solar Max*, which was also sensitive to high-energy neutrons, started detecting solar flare neutrons only about one hundred seconds after the hard x-rays arrived at the spacecraft. Because x-rays travel the 93 million miles from the Sun to Earth at the speed of light, these observations implied that the neutrons had a velocity not much slower than light — about eight-tenths of light speed, in fact. A neutron with this velocity has a huge kinetic energy and can only be produced in nuclear reactions occurring between protons accelerated by up to a billion volts and atoms in the solar atmosphere.

Based on these unprecedented observations, solar scientists have concluded that flares act as colossal particle accelerators. These accelerated particles strike atoms in the solar atmosphere along the particles' path, producing the x-ray and gamma-ray emission, while the ultraviolet and optical radiation comes from the hot gases created by the particle bombardment.

This picture of energetic particles bombarding the



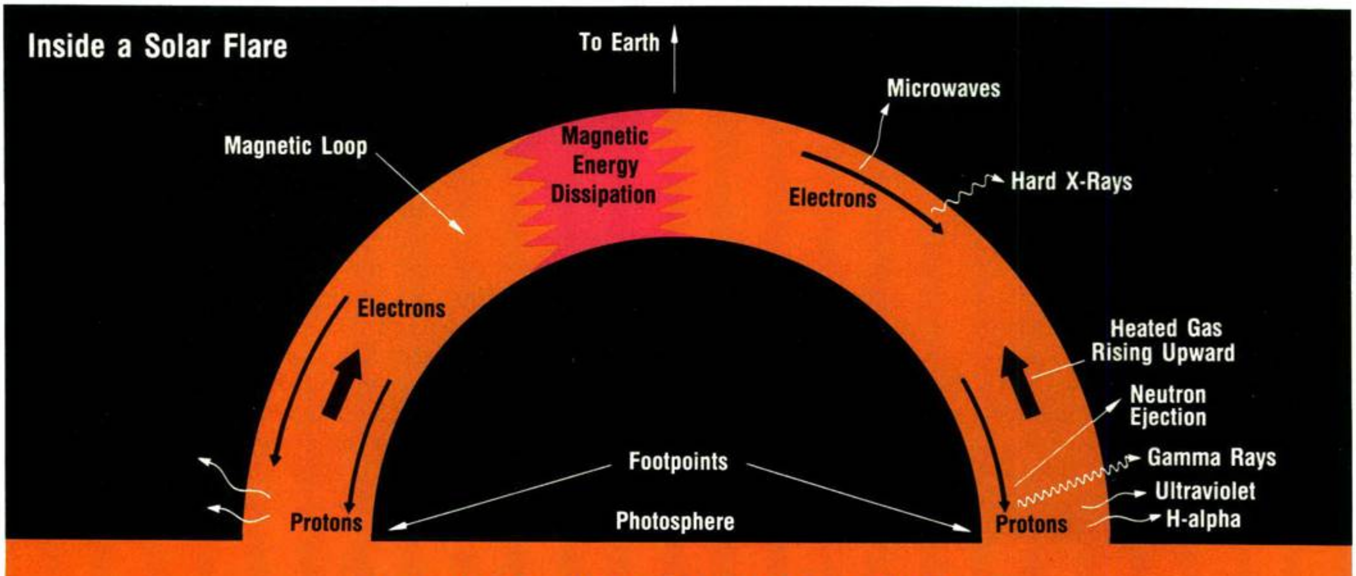
As a solar flare develops, electrons heat the gas where the magnetic loops enter the solar surface, which causes the "footpoints" to radiate high-energy x-rays (white). The lower temperature gas in the magnetic loops radiates low-energy x-rays (blue, red, yellow, and green). Image from the hard x-ray imaging spectrometer on the *Solar Maximum Mission* satellite, courtesy A. Gordon Emslie.

solar atmosphere is supported further by results from the hard x-ray imaging telescope on *Solar Max*. Early in the development of a flare, just as the hard x-ray flux starts to rise, the radiation appears to come from two distinct regions separated typically by a few tens of thousands of miles. A comparison of this information with data obtained with Earth-based magnetographs, which map the strength and polarity of the Sun's magnetic field, shows that these regions correspond to the ends of a twisted arch of magnetic flux that has its two feet rooted in the surface of the Sun. (These loops were first observed clearly in ultraviolet and low-energy x-ray images obtained with the instrument package on *Skylab*.) As the flare progresses, the x-ray emission comes from a much broader region of this magnetic loop centered halfway between the original "footpoints."

Theoretical studies of the response of the solar atmosphere to a bombardment by a large number of particles show that the material initially situated in the lower atmosphere at the ends of the loop will be heated by friction with the particles. This material then expands and rises up the magnetic loop, filling the loop with the hot, dense gas responsible for the hard x-ray emission later in the event. Having "blown off" the upper part of the atmosphere, the electrons then heat the dense lower regions, which causes the bright enhancements in spectral lines such as H-alpha. A close look at the "seahorse flare" on page 19 shows that filamentary structures, some bright and some dark, correspond to loops of material with their footpoints embedded in the bright emitting region.

According to the electron-bombardment model, the material in the loop moves upward as a result of strong gas pressures created by the electron heating. Radiation from this material should be shifted toward shorter wavelengths in accord with the Doppler effect, because the rising material is approaching Earth. This shift was confirmed by observations of eighteen-times-ionized calcium made with the low-energy x-ray spectrometer on *Solar Max*. (Stripping eighteen electrons from a calcium atom requires temperatures above 10 million degrees Celsius, so emission from this ion occurs only in the high-temperature material produced during solar flares.) Precise measurements of the amount of the Doppler shift enabled astronomers to determine that the material moves at a velocity of a few hundred miles per second. This result closely corresponds to those of computer simulations of

**Inside a Solar Flare**



Astronomers believe solar flares occur when magnetic loops projecting from the Sun's surface "snap" from the build-up of stresses, accelerating large numbers of electrons and protons. These charged particles spiral along magnetic field lines, emitting electromagnetic radiation and heating the atmosphere at the base of the loop. This heated material then surges up the loop while gas at the "footpoints" emits H-alpha light.

the solar atmosphere's response to electron bombardment.

### Microwave Observations

The high-energy radiation observed with orbiting spacecraft and the visible light observed with ground-based optical telescopes tell only part of the flare story, because solar flares are also substantial emitters of microwave radiation. This radiation is generated by electrons with energies of several hundred thousand volts as they spiral around the magnetic field lines that comprise the flaring loop. By observing flares in this low-energy region of the electromagnetic spectrum, astronomers gain a different but related perspective of the flare phenomenon.

High-resolution radio images obtained with the Very Large Array (VLA) radio telescope system in Socorro, New Mexico, show that most of the microwave brightness comes from the top of the flare loop, which provides evidence that this is the site where the electrons are accelerated. (Observations of high-temperature gas made by both *Skylab* and *Solar Max* support this contention.) The reason microwave emission from the spiraling electrons is not seen along the entire length of the loop is unclear, but it may be that the microwave energy is absorbed by the denser gas at the feet of the loops.

Observations of the variation in both hard x-ray and microwave brightness with time provide another important clue to the process that accelerates the electrons and protons in a flare. The process must be capable of switching on and off in times as short as ten milliseconds, because the hard x-ray and microwave emission fades this rapidly. This means the electrons responsible for the emission must come to a stop in a similarly short time. Therefore, very dense material must be situated close to the site of electron acceleration (even high-energy electrons travel only about 1,000 miles in ten milliseconds, a relatively short distance on the size scale of solar flares).

This piece of evidence may indicate that a solar flare is a highly complex series of interacting events, each too small to be resolved individually. Such "elementary flare bursts," occurring at a much slower rate, may also be responsible for heating the solar corona to a few million degrees during periods when no obvious flare activity is present. The high temperature of the solar corona has been a puzzle since observations revealed this fact decades ago.

### What Are Flares?

Now that astronomers have had the chance to analyze observations across the electromagnetic spectrum, they have a much better insight into the nature of solar flares. Although the following picture is still controversial to some extent, it is qualitatively consistent with the observational data. In the few days preceding a major flare, motions in the Sun's lower atmosphere twist and massage the magnetic loops protruding from the Sun's surface. At some point the stresses on the loops become too great and the loops "snap," ejecting material from the Sun and accelerating huge numbers of electrons and protons. These charged particles spiral through the solar atmosphere along magnetic field lines, generating hard x-rays and microwaves and heating the lower atmosphere. Driven upward by the strong gas pressures so created, material at temperatures of several million degrees fills the flare loop, causing the loop to glow brightly in x-rays. At the same time the lower regions of the loop shine brightly in ultraviolet and optical light. After the particle acceleration ceases, the flare loop relaxes back to its original state and the high-energy radiation disappears.

This picture is not without problems. Extracting 10 billion billion kilowatt-hours of flare energy from the Sun in as short a time as observations demand is not easy. And it is even more difficult, according to current theories, to produce this energy in the form of accelerated particles. Some solar scientists argue, therefore, that the primary energy release in solar flares may involve the heating of a large volume of gas to temperatures of hundreds of millions of degrees Celsius. This hot dense gas could emit hard x-rays and also transport energy to the rest of the atmosphere.

Perhaps a solar flare is really some form of hybrid process that involves both heating and acceleration. If this is so, the same combination of processes may not produce all solar flares. Our theoretical understanding of these enigmatic events is still at a fairly rudimentary level, which should not be surprising because astronomers believe the flare process involves the interaction of magnetic fields on size scales of centimeters to meters, while the best radio and optical telescopes can at best distinguish features about the size of Texas and the best x-ray telescope can only resolve features about the size of the contiguous United States!

Solar scientists hope to probe solar flares on a finer scale than ever before with new x-ray and gamma-ray imaging telescopes. In a proposal now before NASA, astronomers recommend that each instrument be carried aloft by a separate balloon. Each balloon would be launched from the Southern Hemisphere and climb to an altitude of about 130,000 feet, where it will circle the globe for three to four weeks as the instrument observes solar flares. If this proposal comes to fruition, astronomers may finally unravel the mysterious inner workings of flares. By doing this, they will not only gain a better understanding of solar flares but will be better able to predict solar flares and thereby give advanced warning of their harmful effects. The knowledge gained could also be applied to other stars and to the basic physics of high-temperature gases in, for example, laboratory fusion reactors.

In the 130 years since the initial observations by Carrington and Hodgson, we have learned a great deal about solar flares. Despite the many important discoveries made by recent space missions, however, there is still much about flares we do not fully understand. How does the Sun generate such vast amounts of energy in so short a time? What triggers a solar flare in the first place, and are there ways to precisely forecast the occurrence of solar flares? These are just a few of the questions that continue to challenge the astronomers studying these fascinating events.

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*A. Gordon Emslie is an associate professor of physics at the University of Alabama in Huntsville. His research interests are in solar flare physics and cosmology, and he is a member of the MAX '91 Committee to coordinate the study of solar flares during the next solar maximum.*

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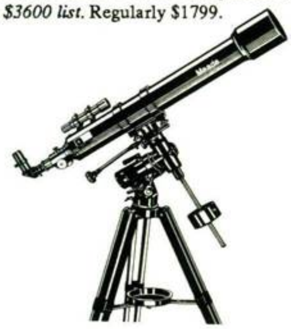

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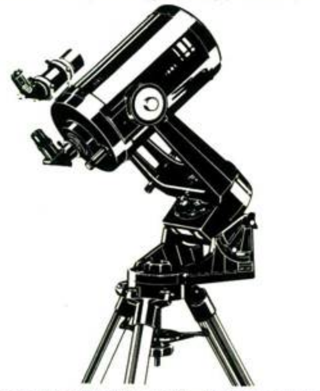

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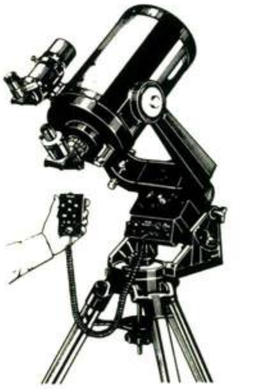

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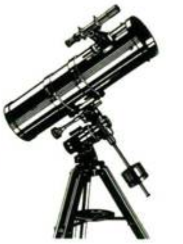

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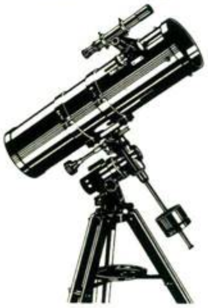

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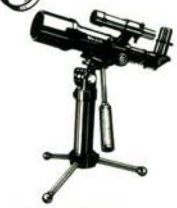

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RETURN TO MARS

# Superpower Pact Links Initial Mars Missions

by Stephen Cole

The first race to Mars was in full swing fifteen years ago. By 1972 the Soviet Union had already launched eleven missions to Mars, the United States six. The U.S. *Mariner 9* was orbiting the planet and had returned the first photos of Phobos and Deimos, the two Martian moons. The Soviets launched four spacecraft in the summer of 1973, but three of these failed and the Soviets dropped out of the race. In 1975 the United States launched the *Viking* mission — the country's single most expensive planetary mission ever undertaken — and successfully landed two spacecraft on Mars.

Over a decade has passed since either country has mounted a mission to Mars. Now both superpowers are poised at the starting line of what looks like a second race to the Red Planet. Less than nine months from now the Soviet Union will launch the two *Phobos* spacecraft to explore Mars and its moons. The U.S. *Mars Observer* orbiter mission, which has been postponed until 1992, was originally set to launch in 1990. Both countries are planning additional missions: the Soviets will return in 1992 with the *Vesta* mission; the United States is studying Martian rovers and sample-return missions.

The race to Mars appears to be on again, but this past spring the two nations changed the rules of the game.

**Exploration of Mars resumes with the Soviet *Phobos* mission in 1988 and the U.S. *Mars Observer* mission in 1992.**

Previously an individual event pitting the Soviets against the Americans, this race may be more of a relay with the former competitors both on the same team.

An agreement "concerning cooperation in the exploration and use of outer space for peaceful purposes," signed in Moscow on April 15, outlines sixteen projects in five fields of space science and astronomy that the two countries will work together on. Four of the projects deal with Mars exploration:

1. Coordination of the *Phobos*, *Vesta*, and *Mars Observer* missions and the exchange of scientific data resulting from them.
2. Utilization of the U.S. Deep Space Network for position tracking of the *Phobos* and *Vesta* landers and subsequent exchange of scientific data.
3. Invitation by mutual agreement of co-investigators' and/or interdisciplinary scientists' participation in the *Mars Observer* and the *Phobos* and *Vesta* missions.
4. Joint studies to identify the most promising landing sites on Mars.

Both countries stand to benefit from the agreement. The Soviets gain access to unique U.S. facilities and expertise, such as the Deep Space Network, that will increase the scientific yield of their missions. The United States obtains access to Soviet Mars data and involvement in the Soviet program at a time when U.S. plans are delayed.

"The Soviets have really taken the lead in inner solar system research," says Geoffrey Briggs, director of NASA's solar system exploration division. "I'd like to say that access to Soviet data was not important to U.S. scientists, but our programs are so delayed that the Soviet data may be as valuable as our own."

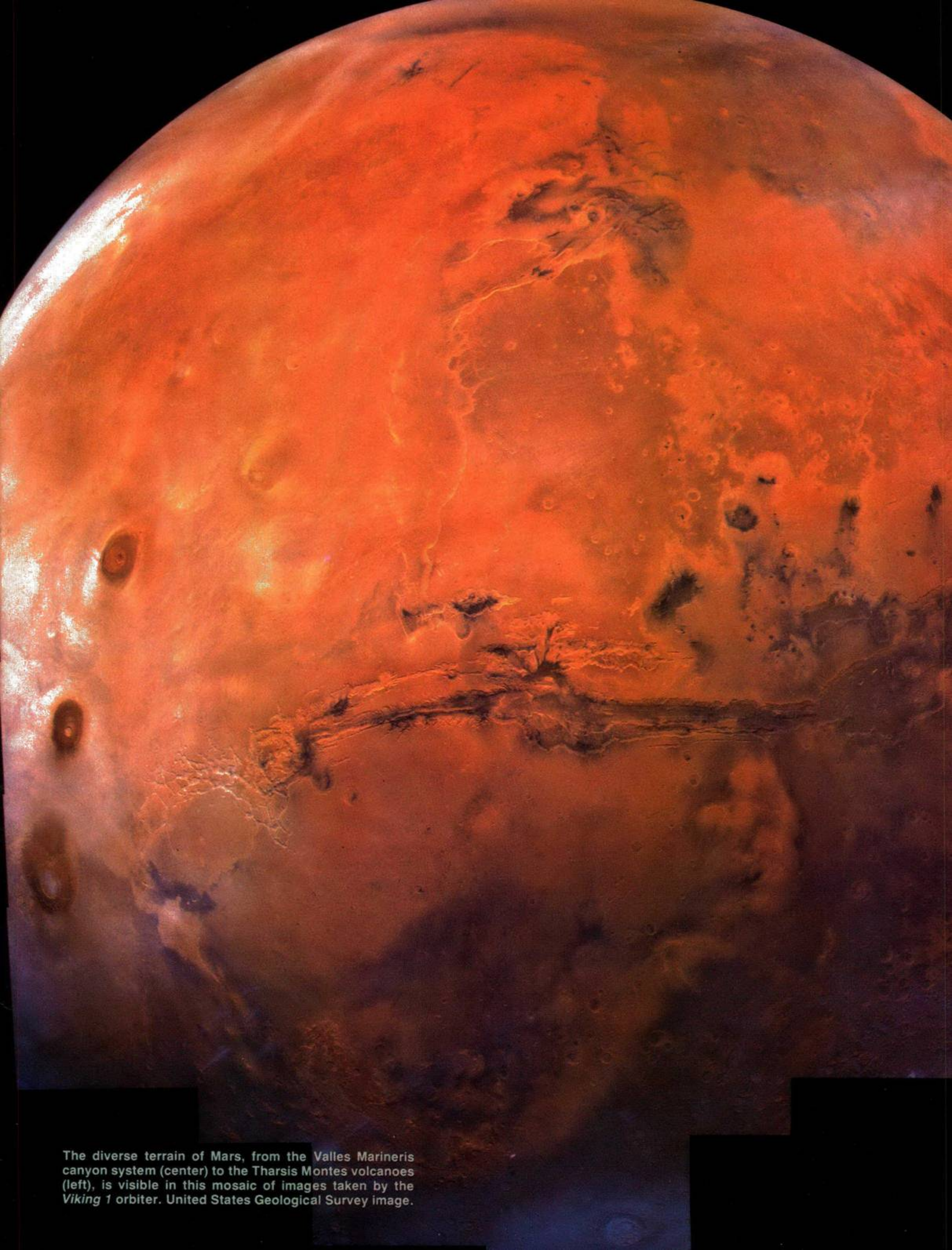
Soviet data, which had been received on an informal, piecemeal basis in the past, is now expected to comprise all of the original data from an experiment. The data will be made available to the entire U.S. scientific community, not just individual researchers.

The agreement with the Soviets may also have the indirect benefit of reinvigorating the U.S. space program. "We have to get our program in order to be competitive, even cooperative, in the future," says Ray Arvidson, professor of earth and planetary sciences at Washington University and *Mars Observer* interdisciplinary scientist for data management and archiving. "This agreement takes us off of dead center.

"We find ourselves at a time of opportunity where ironically we can't act or at least can't act quickly enough," Arvidson says. With no other way to get missions into space than the shuttle, which has been grounded for almost two years, several planetary exploration missions, including *Mars Observer*, have been delayed.

"The 1990s could be a really exciting time for space studies, a new era of cooperation and new discoveries," says Arvidson. "Or if you want to be pessimistic, from the U.S. perspective it could be the era that never got off the ground."

The agreement establishes five general areas of scientific cooperation: solar system exploration, space astronomy and astrophysics, earth sciences, solar-terrestrial physics, and space biology and medicine. Specific projects include exchanging data on cosmic dust, the



The diverse terrain of Mars, from the Valles Marineris canyon system (center) to the Tharsis Montes volcanoes (left), is visible in this mosaic of images taken by the *Viking 1* orbiter. United States Geological Survey image.

# SOVIET / U.S. EXPLORATION OF MARS: 1960-1987

## SOVIET UNION

**1960**
*Mars-1960A*, *Mars-1960B*: Flyby missions, launched October 10 and 14, both failed to reach Earth orbit.

**1962**
*Mars-1962A*: Flyby mission, launched October 24, failed to leave Earth orbit. *Mars 1*: Flyby mission, launched November 1, contact lost en route. *Mars-1962B*: Flyby mission, launched November 4, failed to leave Earth orbit.

**1964**
*Zond 2*: Flyby and possible lander mission, launched November 30, contact lost en route.

**1969**
*Mars-1969A*, *Mars-1969B*: Possible lander missions, launched March 27 and April 14, failed to reach Earth orbit.

**1971**
*Kosmos 419*: Orbiter/lander mission, launched May 10, failed to leave Earth orbit. ***Mars 2***: Orbiter/lander mission, launched May 19, successful orbiter but lander failed. ***Mars 3***: Orbiter/lander mission, launched May 19 and May 28, successful orbiter but lander failed after 110 seconds on surface.

**1973**
*Mars 4*: Orbiter mission, launched July 21, flyby instead of orbiter because of retrorocket failure. ***Mars 5***: Orbiter mission, launched July 25, successful orbiter. *Mars 6*: Flyby/lander mission, launched August 5, contact with lander lost before landing. *Mars 7*: Flyby/lander mission, launched August 9, lander missed the planet.

## UNITED STATES

**1964**
*Mariner 3*: Flyby mission, launched November 5, booster failure. ***Mariner 4***: Mars flyby, launched November 28, first successful flyby and return of images.

**1969**
***Mariner 6***, ***Mariner 7***: Flyby missions, launched February 25 and March 25, successful photographic flyby.

**1971**
*Mariner 8*: Orbiter mission, launched May 8, booster failure. **Mariner 9**: Orbiter mission, launched May 30, mapped most of Martian surface and returned first photos of Martian moons.

**1975**
***Viking 1***, ***Viking 2***: Orbiter/lander missions, launched August 20 and September 9, first soft landings and surface images.

Successful missions are indicated by ***bold type***.

Venusian surface, meteorites, and lunar materials; coordinating investigations of gamma-ray bursts, solar terrestrial physics, and global changes of the environment; and joint biomedical space research.

The agreement stipulates that joint working groups will be formed to carry out the specific projects in each of the five areas. The space biology and medicine working group was the first to meet this past summer. The solar system exploration group will be next with a meeting this winter.

"Meetings with the Soviets will initially only address items outlined in the agreement," says Briggs. "At the first meeting of the solar system exploration group we will discuss Soviet participation on *Mars Observer* and find out from the Soviets how many people they would like to get involved."

Although no Soviet scientists have been selected yet for U.S. missions, informal American involvement with the upcoming *Phobos* mission has already begun. Six U.S. scientists received invitations from the Soviets before the agreement was made to study data returned by *Phobos*. Seven other scientists are working as co-investigators on several of the European experiments flying aboard *Phobos*.

With a formal agreement now in hand, future involvement between U.S. and Soviet scientists will no longer be on an informal, individual basis. "Invitations will be handled on a more competitive basis, giving the entire U.S. community a chance at these opportunities to get involved with Soviet projects," says Briggs. NASA will now review proposals for Soviet projects and will provide funding for cooperative projects.

The first Mars-related project to be initiated is the Soviet use of NASA's Deep Space Network in the *Phobos* mission. "Because time is passing rather rapidly with respect to the *Phobos* launch next summer," says Briggs, "we have established an actual operational link with the Soviets on use of the network for tracking the *Phobos* landers."

Engineers from both countries have already met to discuss the compatibility of Soviet and U.S. equipment and determine the amount of tracking time available. The Network's precise tracking capability will allow the Soviets to refine the estimated mass of Phobos and Phobos' orbit.

Although the agreement does not mention Mars missions beyond those currently under way, there is nothing in the agreement to prevent discussions about future projects such as sample-return and joint manned missions. According to Briggs, "Other agenda items can be raised at the working group meetings as the participants choose, but only after high-level approval."

Continued cooperation with the Soviets makes practical — and economic — sense, especially in this era of "resource-limited" NASA budgets, Arvidson points out. "Our remote sensing technologies, more specifically our imaging spectrometers, are much more advanced with higher resolution and more distinct images compared to Soviet systems. But the Soviets have the powerful Proton rocket and some aggressive ideas about missions that can benefit us."

The agreement signed in Moscow will expire in five years, and the first leg of the race to Mars will be complete. Hopefully the second leg will begin at that time with an equally promising start.

RETURN TO MARS

# Soviet *Phobos* Mission to Probe Moons of Mars

by Donald Frederick Robertson

The Soviet Union is returning to Mars in a big way. Back-to-back launches next July will send two spacecraft toward Mars that will orbit and map the planet, drop two types of landers on one or both of Mars' moons, and poke at the moons' surfaces with a laser.

The *Phobos* mission to Mars and its moons is easily the most ambitious and difficult planetary mission the Soviet Union has attempted. It is also one of the most international space exploration missions ever undertaken. Austria, Bulgaria, Czechoslovakia, East and West Germany, France, Hungary, Poland, Sweden, the European Space Agency and, at least indirectly, the United States are contributing instruments or scientists.

The *Phobos* mission consists of three different activities: orbiting Mars, hovering very close to the surface of Phobos, and dropping landers onto Phobos. Experiments on both spacecraft will study the Martian surface, atmosphere, and magnetic field from orbit. One spacecraft will briefly hover above Phobos, mapping the surface and subsurface of the moon and studying its composition. Two landers — one that will bore into the moon and another that will "hop" to several locations — will study the composition and structure of Phobos from the surface.

Other experiments conducted during the flight to Mars will study the interplanetary medium, the solar wind, and the Sun. But the primary focus of the mission is Phobos, a tiny, elliptical moon that some astronomers suspect may be an asteroid formed in the early stages of the solar system's evolution and later captured by Mars. It is Phobos' possible primitive nature that makes it an intriguing object of study.

First photographed close up by *Mariner 9* in 1971, the surface of Phobos is heavily cratered and covered by a thin layer of debris, or regolith. One large crater, Stickney, measuring 6 miles across, dominates the elliptical moon, which is 11 miles by 16 miles across. Long grooves on the surface radiate from Stickney and cover much of Phobos. These features are believed to be fractures produced by the impact that formed the crater.

Phobos and its smaller sister moon, Deimos, have very low densities, only about twice as dense as water. This property, in addition to Phobos' very dark surface, are similar to carbonaceous chondrites, a type of stony meteorite rich in water and organic compounds. Unlike other meteorites, carbonaceous chondrites rarely make it to Earth because of their fragile structure. They may, however, be the most primitive objects in the solar system.

### The Soviets' New Planetary Focus

According to Valeriy Barsukov of the Vernadsky Institute of Geochemistry and Analytical Chemistry in Moscow, the Soviet program for automated planetary exploration will principally concentrate on Mars and the small bodies of the solar system for the next ten years. *Phobos* follows the successful Soviet *Vega* mission to another small and primitive body — Comet Halley — in 1986.

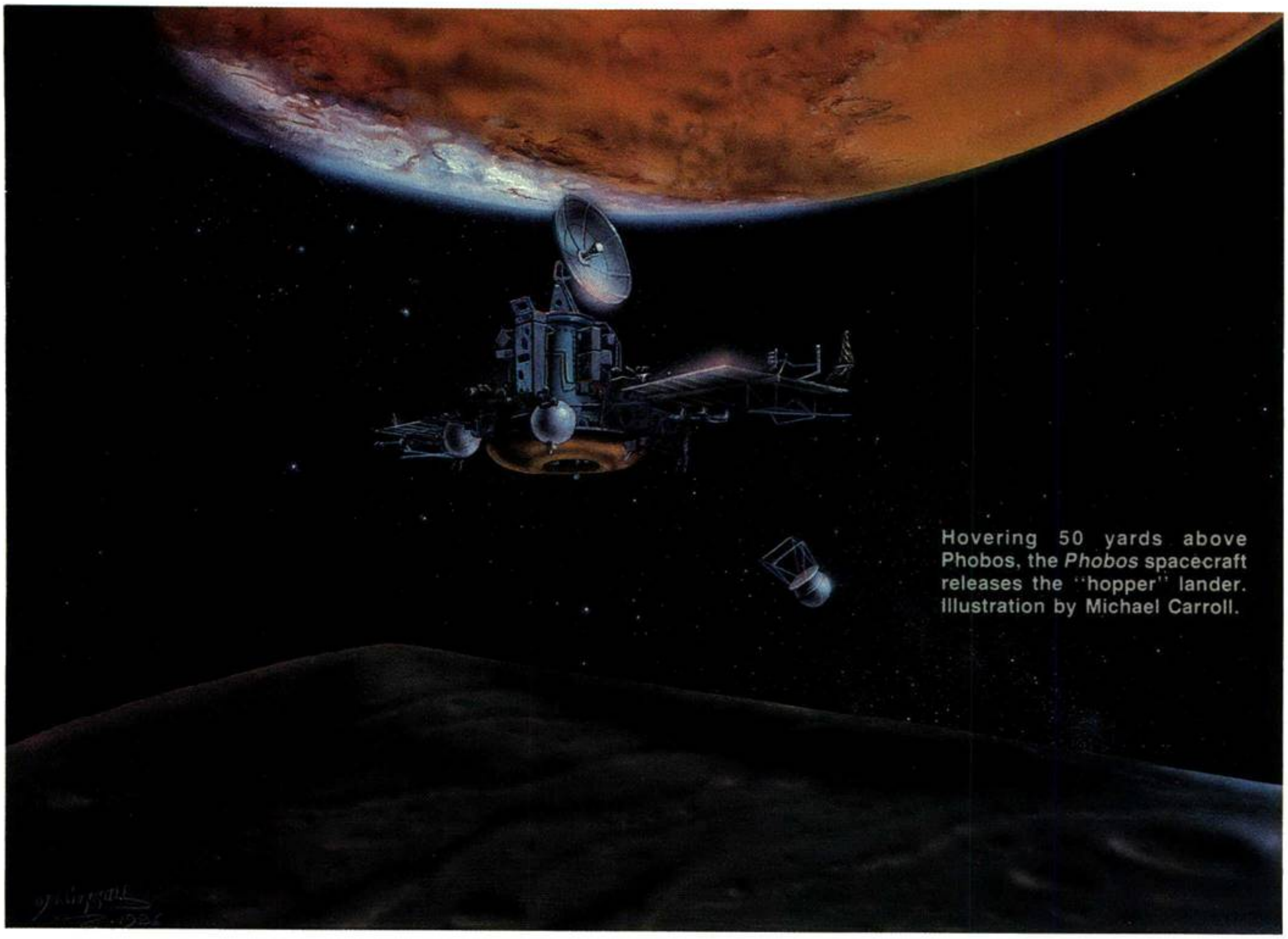
Barsukov discussed the details of the *Phobos* mission at the First International Conference on Solar System Exploration held in Pasadena, California, this past May. In July 1988 two giant Proton launch vehicles will lift off, a few days apart, from the Baikonur Cosmodrome at Tyuratam in Soviet Central Asia. Minutes after launch the first of a new generation of production-line built interplanetary spacecraft will arrive in a temporary parking orbit. Once the initial low Earth orbit has been carefully measured, powerful upper stages will send each ship toward Mars.

**The Soviet program for planetary exploration will concentrate on Mars and the small bodies of the solar system for the next ten years.**

Roald Kremnev, director of the Babakin Center of Moscow's new civilian space agency, Glavcosmos, told the Solar System Exploration Conference the new spacecraft are designed for diverse investigations. The basic craft can be modified for use as a lunar polar orbiter and for Mars sample-return missions.

Each *Phobos* ship will carry approximately thirty instruments. In sharp contrast to the design of U.S. spacecraft, which are open to vacuum, the *Phobos* spacecraft are pressurized and the interior gas is circulated to cool the electronics. Scientific data are stored on board and transmitted to Earth after the spacecraft has left the vicinity of Phobos.

The mission design — with separate landing and orbit-



Hovering 50 yards above Phobos, the *Phobos* spacecraft releases the "hopper" lander. Illustration by Michael Carroll.

ing capabilities — permits thorough study of Phobos without contaminating Phobos' surface. Kremnev indicated that *Phobos* mission management originally planned to land the spacecraft on Phobos. However, Soviet scientists later decided it would be safer to conduct most measurements from a distance and deploy only small, specialized landers.

"The experiments must be conducted in such a way that the primeval condition of the surface of [Phobos] is not violated," explains Georgiy Managadze, director of the laboratory designing the mission's laser probe, in a Soviet scientific journal. "A vehicle could not land on Phobos without leaving any traces: landing engines would contaminate Phobos' surface."

Other advantages to not landing the main spacecraft result from the ability to hover in Phobos' weak gravity for long periods of time and to drift over the surface, which allows more of Phobos to be studied than would be possible from a single landing site.

### Synchronizing with Phobos

After two hundred days in transit the spacecraft will arrive at Mars in January 1989. They will orbit above the Martian equator where they can observe Mars and align with the orbit of Phobos. The first thirty days after arrival will be spent getting into position. Each *Phobos* spacecraft fires its main rocket, entering a three-day elliptical "transfer orbit" around Mars with a low point of 500 miles. Rockets then fire again to lower the orbits to 300 miles.

One of the two spacecraft is then placed into a circular "observation" orbit 3,900 miles above the planet's equator, which is about 200 miles higher than Phobos. In its new orbit this spacecraft moves around Mars at a slightly slower rate than Phobos' 7-hour-and-39-minute orbital period, which results in a number of distant, slow flybys of the moon. The second spacecraft, meanwhile, remains in the transfer orbit, studying Mars.

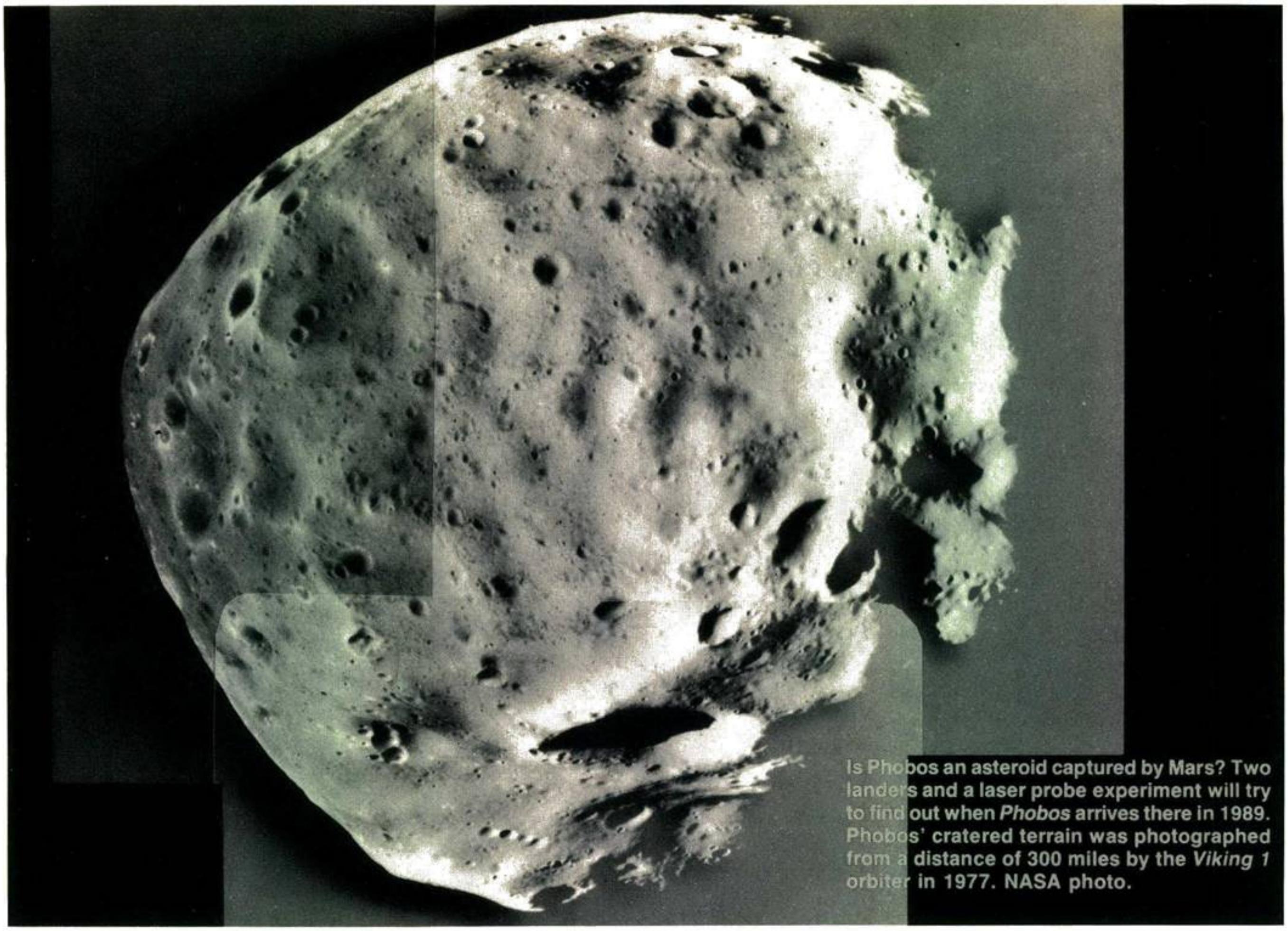
Because the U.S. *Viking* orbiters did not measure Phobos' orbit well enough to allow a close approach, the first spacecraft has to more accurately determine Phobos' orbit. This is done by measuring the relative movements of the spacecraft and Phobos in the observation orbit, a process that requires another thirty days.

Afterward Soviet mission control will be able to instruct the spacecraft to transfer into an orbit synchronous with that of Phobos. The spacecraft spends up to sixty days in this synchronous orbit. Here it can study the Martian moon from as close as 20 miles away, taking photographs and further measuring Phobos' position.

Finally the spacecraft's engines fire and the moon's gravity pulls it into what Kremnev calls a "controlled fall." This descent takes about an hour.

The spacecraft is carefully targeted to remain on the side of Phobos facing Earth, so the moon does not interrupt the radio link with Moscow. When the spacecraft is about 1.5 miles away, a Doppler radar locks on to the surface, indicating the spacecraft's velocity relative to Phobos. A radioaltimeter mounted on the back of a solar panel constantly measures the craft's distance from Phobos. When the ship reaches an altitude of about 50 yards, thrusters fire to reduce its sideways velocity.

The *Phobos* spacecraft flies over the moon at a distance of 50 to 70 yards for about fifteen minutes, using the radioaltimeter to maintain clearance over mountains



Is Phobos an asteroid captured by Mars? Two landers and a laser probe experiment will try to find out when *Phobos* arrives there in 1989. Phobos' cratered terrain was photographed from a distance of 300 miles by the *Viking 1* orbiter in 1977. NASA photo.

and crater walls rising above the extremely rough surface. This flight has to be entirely automatic, because radio signals take over six minutes to travel from Mars to Earth and back again.

V. Kovtunenko, corresponding member of the U.S.S.R. Academy of Sciences, says a close flyby over an area with poorly studied relief "is possible only by using onboard control systems capable of automatically evaluating the situation and rapidly making appropriate 'decisions'." The *Phobos* spacecraft has two completely redundant computers "capable of solving problems of a quite high 'intellectual level'," according to Kovtunenko.

### The 'Peaceful Laser'

As the spacecraft drifts over the surface, a high-powered laser mounted on the side of the craft "illuminates" several small and widely separated points. According to Yuriy Zaytsev of the Academy of Science's Space Research Institute, "A thin layer of regolith will be explosively evaporated and transformed into plasma. On the basis of the time required for the plasma to travel from the surface to the vehicle, a special spectrometer will determine Phobos' composition. Approximately a million particles will be registered during one cycle."

"With sufficient laser power," Managadze adds, "the ions that are formed by vaporization of a small segment of Phobos' regolith can rise from the moon to a rather high altitude. The spacecraft will capture them in a 'trap', and instruments will determine the mass spectrum of the particles and send the data to Earth. We plan to take about 150 shots at the surface of Phobos with this peaceful laser."

Another instrument, the ion beam, which is also bolted to the side of the spacecraft, uses a special onboard accelerator to create a flux of krypton ions. "Each hundredth krypton ion is expected to dislodge an ion of regolith matter," says Zaytsev. "An analysis of these secondary particles makes it possible to study the composition of the uppermost layer of surface material."

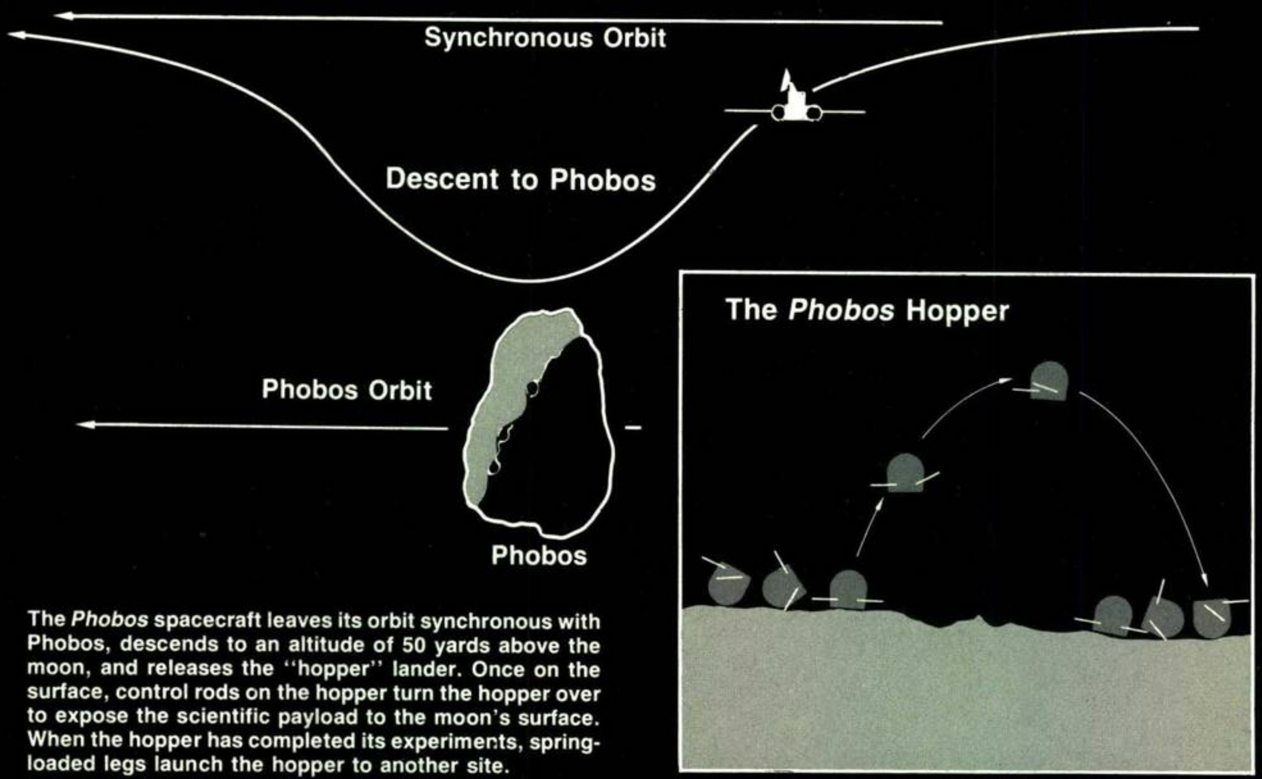
After what the Soviets call the "radiation processing" of Phobos' regolith is complete, mission controllers prepare for their next major experiment. A manipulator on the side of the mother craft points one of the landers at Phobos and releases it and then repeats the process for the second lander.

After drifting toward the surface, one lander, called the "hopper," studies the mechanical characteristics of Phobos' regolith by measuring the regolith's reaction to the hopper's landing forces. A mass spectrometer examines the chemical makeup of the regolith. When done at one site, the lander hops to another location with spring-loaded legs to repeat its measurements. During hops the probe maps the moon's gravity field in an attempt to understand what lies underneath the surface.

The second lander, called the "long-term automated lander," clamps itself to the surface with a drill and immediately begins to take a panoramic photograph. This fixed lander has three wings of solar arrays extended parallel to the surface of Phobos in a "Y" pattern. The lander takes photographs with a French-made camera that turns a full 360 degrees and can look up at the sky and back down to the surface immediately beside the lander.

The lander also carries a West German-designed alpha backscatter and x-ray spectrometer that analyzes the chemical composition of the surface, confirming meas-

## "Hopping" around Phobos



**The *Phobos* spacecraft leaves its orbit synchronous with Phobos, descends to an altitude of 50 yards above the moon, and releases the "hopper" lander. Once on the surface, control rods on the hopper turn the hopper over to expose the scientific payload to the moon's surface. When the hopper has completed its experiments, spring-loaded legs launch the hopper to another site.**

urements made with the laser and ion experiments on the mother craft and the mass spectrometer on the hopper.

### Listening for 'Phobos Quakes'

A seismometer on the fixed lander will look for "Phobos quakes" caused by temperature changes as the moon moves in and out of Mars' shadow. If any are detected, they may allow scientists to estimate what the deep interior of the moon is like. Specifically, says Kremnev, researchers want to know if Phobos is a single, solid body or a loose collection of smaller bodies.

Soon after the landers are deployed, the mother craft briefly fires its rockets to lift it back to an altitude of 1.5 miles. Here 20-meter "whisker" radar antennae push out from the spacecraft to study the subsurface layers of Phobos' surface. The resolution of this underground mapping is expected to range from 150 meters to less than one meter.

The surface of Phobos will also be mapped with charged-couple device cameras on the main spacecraft. These should provide spectacular panoramic photographs with a resolution of 3 to 6 centimeters.

Meanwhile, the spacecraft still orbiting Mars photographs the Martian surface at infrared, visible, and ultraviolet wavelengths. Gamma and neutral spectrometers will measure the water abundance both at and a small distance under the Martian surface.

"This part of the flight program in particular provides for the conducting of a television survey [of Mars] with high resolution," according to Zaytsev. "One of the objectives of the radiometric and photometric measurements will be to obtain a temperature map of the surface, study the diurnal and seasonal dynamics of the temperature regime, determine the thermal inertia of the surface material, and search for regions of permafrost, as well as sectors with [volcanic activity]."

At the Solar System Exploration Conference Barsukov said: "At the present time we are not planning to send the backup spacecraft to Mars' other moon, Deimos, but if the encounter with Phobos is successful, Deimos may be considered."

The spacecraft, as they are traveling to Mars and while they are orbiting Phobos, will also be observing the Sun to study solar flares and the solar corona. These data, when combined with data taken simultaneously on Earth, give scientists a stereoscopic view of the Sun. Scientists hope these three-dimensional measurements will detect solar oscillations resulting from the propagation of sound waves through the Sun. Just as on Earth, measurement of these "sun quakes" will allow scientists to study in detail the deep interior of the Sun.

The multipurpose *Phobos* mission, as ambitious as it is, will be followed by a series of even more ambitious missions by the Soviets in the near future. At the Solar System Exploration Conference Kremnev outlined a three-stage program beginning with launches in 1992. Using balloons, surface penetrators, and rovers to explore the planet, the Soviet program will culminate with the return of Martian samples to Earth.

For the Soviets the next decade of Mars exploration is shaping up to be a very active — and exciting — one.

*Donald Frederick Robertson is a freelance writer based in San Francisco and a frequent contributor to* ASTRONOMY *on current space missions.*

RETURN TO MARS

# U.S. *Mars Observer* Seeks Global Picture

by Donald Frederick Robertson

"When *Mars Observer* completes its 700-day survey of Mars, we will have a more comprehensive global picture of that planet than we currently have of Earth," says Ray Arvidson of Washington University, the man responsible for getting that data back from *Mars Observer* and into the hands of scientists on Earth.

Because of its very low orbit and sensitive instruments, *Mars Observer* will be able to study Mars in unprecedented detail. The experiments on board the spacecraft will map the elemental composition and mineralogy of the entire surface, study the circulation of the Martian atmosphere, and follow the movement of dust and volatiles such as carbon dioxide and water through a complete seasonal cycle.

"*Mars Observer* will look at the surface and the atmosphere of Mars in a very systematic way," says mission project scientist Arden Albee of the California Institute of Technology. "The experiments will produce synergistic data sets to attack a wide variety of questions."

An intensive study of the global characteristics of Mars was not one of the objectives of the most extensive Mars mission to date, the U.S. *Viking* mission, launched in 1975. The two *Viking* orbiters carried only three scientific instruments: a television camera system, a thermal mapper, and an atmospheric water detector. The two landers analyzed soil samples but only at two widely separated locations.

"To a certain extent *Viking* was out of sequence in the usual order of exploratory missions," says Albee. "Because of the strong desire at the time to detect life on Mars, the mission left a lot of unsettled questions. It was missing instrumentation that would tell us what the nature of the soil was and where the water was."

"We're basically ignorant about the composition of Mars," says Bonnie Buratti of the Jet Propulsion Laboratory, who is working on the mission's Infrared Mapping Spectrometer team. "And with NASA's long-range Mars Initiative looking at future sample-return and manned missions, *Mars Observer* has become kind of critical. We can't just look at a couple of places; we have to case out the whole planet."

In addition to *Mars Observer*'s prime objective of global study, another major objective is to understand both the history and the current location and distribution mechanism of Martian volatiles. "There is a tremendous seasonal transport of volatiles on Mars," says Albee. "Twenty-five percent of the atmosphere disappears and reappears each Martian year. We want to understand that seasonal cycle."

*Mars Observer* will investigate these questions with ten instruments, many of which are similar to those on meteorological and Earth-resources satellites orbiting Earth. The spacecraft itself, which is being constructed by RCA, is based on designs used in Earth-orbiting communications and weather satellites.

### Year-Long Journey to Mars

Scheduled for launch from the space shuttle in the fall of 1992, *Mars Observer* will travel for one year before reaching Mars. It will orbit the planet from pole to pole at an average altitude of only 225 miles. The orbit will stay oriented toward the Sun, which will always be kept at a 2 o'clock position in relation to the spacecraft, to make the most of the available sunlight at Mars. The mission will last at least 687 Earth-days, or one full Martian year.

> **"We're basically ignorant about the composition of Mars. We can't just look at a couple of places; we have to case out the whole planet."**
>
> **— Bonnie Buratti, Jet Propulsion Laboratory**

Although *Mars Observer* is a relatively low-cost mission with a budget of just $212 million, it will conduct a lot of science for its size. According to Albee, "The payload is more advanced than any we've ever flown. *Mars Observer*'s ratio of payload to spacecraft mass is higher than ever before, and the number of dollars spent on the payload is higher compared to total spacecraft cost than is usually the case."

Four different experiments will examine the nature of Martian surface composition. Phillip R. Christensen of Arizona State University, principal investigator on one of these instruments, the Thermal Emission Spectrometer, believes the *Viking* lander data told us very little about the planet's overall makeup. The spectrometer will measure the way Mars absorbs infrared radiation — heat —which depends on the crystal structure of surface rocks. This in turn depends both on what the rocks are made of and at what temperature the rocks solidified, which indicate how far below the surface the rocks were when they formed.

The Thermal Emission Spectrometer will also be able to suggest whether the early Mars had liquid water on its surface. If water was present on Mars' surface in the past, it might have reacted with the Martian carbon dioxide atmosphere to create carbonates, which can be detected from orbit. Likewise, if *Mars Observer* detects salt deposits on the surface, this could imply that running water had leached the salts from Martian rocks. While Christensen said he does not "necessarily expect to find ancient oceans," his instrument may be able to find the minerals deposited by hot springs. Such a discovery would suggest that water exists below the surface and is heated by current volcanic activity.

*Viking* proved water ice was a significant constituent of the summertime polar caps but could not measure how much water there is. Christensen hopes to find out. Also, by looking at the polar caps from different directions, he should be able to tell whether the polar caps were formed from snow that fell from the air, or whether water and carbon dioxide condensed directly onto the surface as ice.

**"Although the resolution of our camera may be a little too low for safe lander images, if there were cars on Mars, we'd be able to see them."**

**— Michael Malin, Arizona State University**

### Mapping the Major Elements

Another instrument, the Gamma-Ray Spectrometer, will provide a much better analysis of the elements present in the surface than the Thermal Emission Spectrometer will but at the price of much poorer detail. Team leader William V. Boynton of the University of Arizona says the experiment will only be able to "see" surface features larger than 125 miles across, but it will be able to distinguish "all of the major elements, including hydrogen."

The experiment does this by recording the energy spectrum of gamma rays given off by Mars' surface. When excited by solar radiation, every element emits gamma rays at a particular frequency, and by measuring the number of gamma rays versus frequency, Boynton expects to be able to determine the relative concentration of different elements.

Boynton also hopes his experiment will reveal something about the interior of Mars. Martian volcanoes are believed to erupt from great depths, so the composition of a volcano can indicate the composition of materials deep under the volcano. The differences between volcanoes can thus be used as a probe of the composition of Mars' deep mantle at different locations.

The detection of hydrogen implies water, because water is the only solid or liquid hydrogen compound likely to be present on the Martian surface. The Gamma-Ray Spectrometer will be able to detect hydrogen to approximately a foot below the surface. The instrument can not tell whether any underground water it finds is ice or liquid, but Boynton said the Thermal Emission Spectrometer may be able to indicate the temperature of hydrogen found below the surface.

The Neutron Detector added on to the experiment should provide a measure of the carbon dioxide content of the polar ice caps. It can also observe water to a depth of three feet and, said Boynton, "it can tell the difference between, say, 1 percent water evenly distributed in the upper one meter or 2 percent water in the lower half meter and none in the upper half."

The Visual and Infrared Mapping Spectrometer will map the distribution of molecular compounds — volatiles and minerals — on the surface. The experiment will determine whether major areas of Mars are made of significantly different minerals. Are the ancient volcanoes of the southern hemisphere made of different kinds of rocks than the relatively young volcanoes to the north? Are there local areas of ground water seepage? Perhaps most importantly Visual and Infrared Mapping Spectrometer scientists hope to tell how much water, nitrogen, and carbon dioxide Martian volcanoes have outgassed into Mars' atmosphere throughout the planet's history.

The experiment will look for clays, sulfates, and salts, as well as the distribution of volatile compounds, especially near the poles. It will map the reflectances of the Martian surface in the fall and again in the spring, measuring how deposits of dust and volatiles change from season to season. Team member Bonnie Buratti hopes to look at wind streaks immediately after a dust storm to see what they are made of and determine the size of the dust particles by observing how their reflectance changes as the angle from which they are viewed changes.

### A Complete Profile of the Atmosphere

*Mars Observer*'s "workhorse atmospheric instrument," as project scientist Albee calls it, is the Pressure Modulator Infrared Radiometer, which will produce a complete, continuous profile of the temperature, pressure, and composition of the Martian atmosphere.

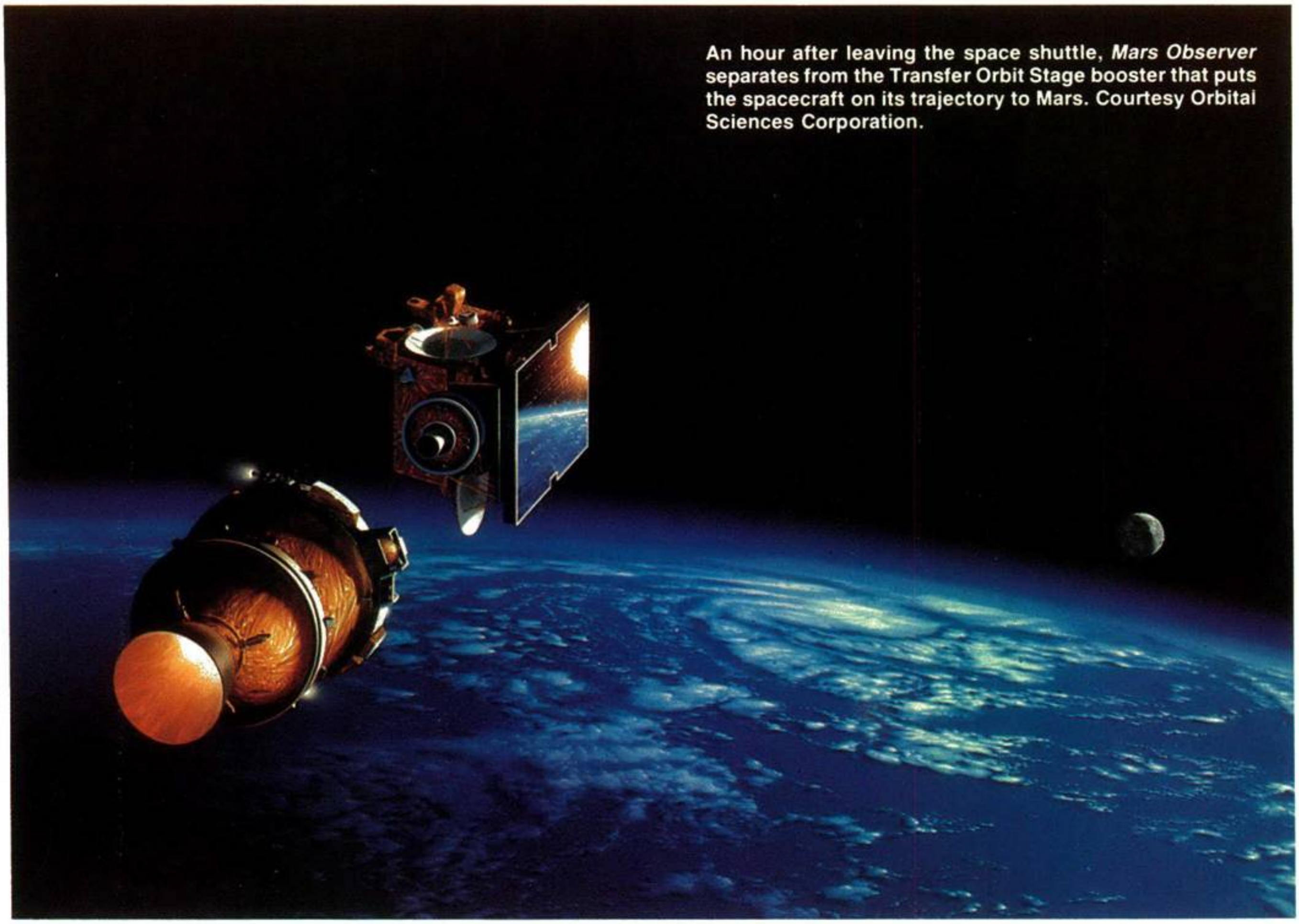
Principal investigator Daniel J. McCleese of the Jet Propulsion Laboratory says the radiometer looks behind the spacecraft to observe the "thermal infrared radiation emitted from gases and dust or ice particles in the atmosphere. These measurements will provide an atmospheric climatology for Mars comparable to that acquired for Earth only in recent years.

"One of the most important phenomena with regard to past and present climates of Mars is the occurrence of global dust storms," says McCleese. The radiometer will be able to see to the bottom of all but the most intense storms, which will allow scientists to study the storms' vertical structure to a resolution of about 3 miles. McCleese hopes to understand the mysterious beginnings of Martian dust storms, which can grow quickly to encompass the entire planet.

The difference between the amount of sunlight the polar ice absorbs and the amount of heat it radiates is called the "polar radiative balance." By measuring this balance, the radiometer can indicate how fast the carbon dioxide of Mars' atmosphere condenses at the winter pole. McCleese said that "understanding the seasonal cycles of carbon dioxide, water, and dust at the poles" can in turn tell scientists about Mars' long-term climate.

A snapshot of Earth's climate requires ten years of observations, according to McCleese. Even if *Mars Observer* lasts for two Martian years — twice its design lifetime — "it will be very difficult to separate year-by-year changes from long-term climate changes" with atmospheric measurements alone. Therefore, the "polar caps are the one thing we can use to directly measure the long-term climate."

The only experiments to look much below the surface are the spacecraft itself in gravity measurements and the magnetometer. Mario H. Acuna of NASA's Goddard



An hour after leaving the space shuttle, *Mars Observer* separates from the Transfer Orbit Stage booster that puts the spacecraft on its trajectory to Mars. Courtesy Orbital Sciences Corporation.

Space Flight Center, principal investigator for the magnetometer, says no Soviet or United States spacecraft has yet directly detected Mars' magnetic field. But many scientists believe Mars does have a magnetic field, and previous spacecraft have simply orbited too far from the planet to directly detect it. Furthermore, the 1.4 Martian-radii distance of the bow shock, where the solar wind rams into a planet's atmosphere or magnetosphere, is too far away to be accounted for solely by Mars' atmosphere. *Mars Observer*'s orbit is so low it is expected to be inside any field.

### Looking for a Magnetic Field

Except for Neptune and Pluto, "Mars is the only planet in the solar system about which we don't have direct magnetic field measurements," says Acuna. Scientists still don't understand exactly how magnetic fields are generated — Acuna describes current theories as "guesses" — which makes the Mars data essential. The more examples of a phenomenon scientists have, the more likely scientists are to understand it.

If the magnetic field is strong enough, "we may be able to relate the structure of the magnetic field to surface features," Acuna adds. Scientists could then study how the crust has formed over geologic ages.

NASA has decided to fly a French experiment called the Electron Reflectometer. Acuna described this instrument as a "remote sensing magnetometer" able to sense magnetic fields below the spacecraft's orbit. (Most magnetometers must be within a magnetic field to detect it.) The reflectometer will measure the distribution and speeds of electrons striking the instrument. From the direction and energy of the electrons Acuna's team hopes to deduce whether the electrons have been reflected from a magnetic field, and if so, the strength and direction of the field.

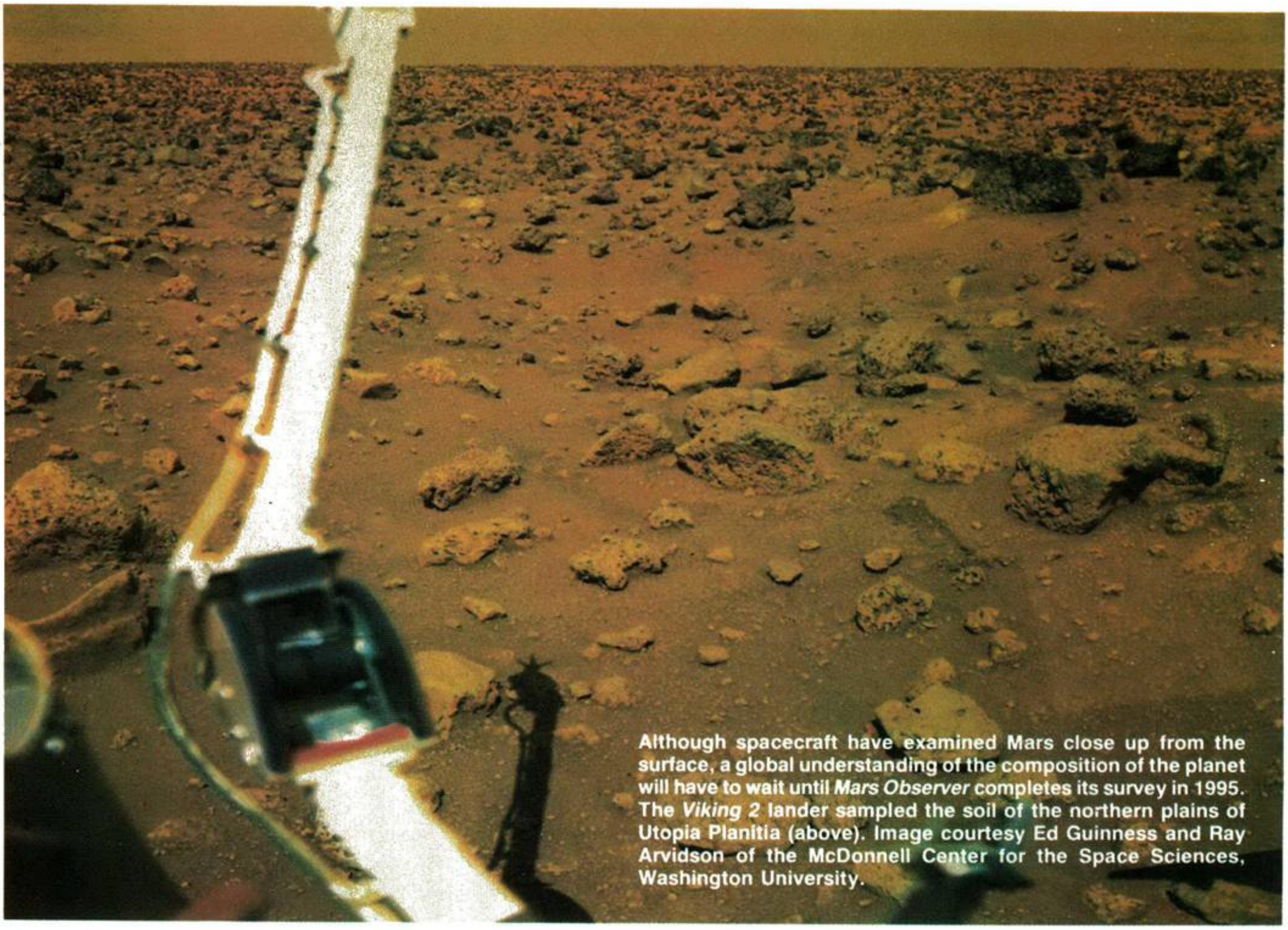
The radio transmissions from the spacecraft will be used to map the Martian gravitational field. To carry out the experiment, an ultrastable oscillator, a device that generates a signal at an extremely precise frequency, will be added to the spacecraft's telecommunication subsystem.

Another experiment that uses *Mars Observer*'s communications link will probe the Martian atmosphere and gravity field. David Hinson, a member of the Radio Science experiment team, said a clock on the ground will send a precisely tuned signal to the spacecraft, which *Mars Observer* will immediately send back to Earth. The observed Doppler shifts in this signal can then be used to tell the spacecraft's exact orbit, which will be perturbed by concentrations of mass within Mars.

Hinson expects individual volcanoes to noticeably affect the spacecraft's orbit. From this the mass of the volcanoes can be estimated. By combining these measurements with altimeter data from the radar, Hinson hopes to "see the way the crust responds to massive features such as Olympus Mons," Mars' highest volcano.

A second clock, this one on the spacecraft, will send a signal through the Martian atmosphere, which will change the signal's amplitude and frequency. From these "radio occultations" Hinson expects to measure both the pressure and temperature in the lower 30 miles of Mars' atmosphere with a vertical resolution of approximately 200 yards.

*Mars Observer* is in a polar orbit, so when one is looking from Earth, the spacecraft passes behind Mars at latitudes greater than 60 degrees. Thus, Hinson's team will



Although spacecraft have examined Mars close up from the surface, a global understanding of the composition of the planet will have to wait until *Mars Observer* completes its survey in 1995. The *Viking 2* lander sampled the soil of the northern plains of Utopia Planitia (above). Image courtesy Ed Guinness and Ray Arvidson of the McDonnell Center for the Space Sciences, Washington University.

be able to measure atmospheric temperatures and pressures only near the poles. However, the all-important polar energy balance can be measured by watching how the polar air pressure changes, which provides an independent check against the Pressure Modulator Infrared Radiometer measurements.

### Fine-Scale Topographic Mapping

Mapping the topography of the Martian surface is the objective of the combined Radar Altimeter and Microwave Radiometer. The radar can measure differences in altitude on Mars of about 25 feet on a smooth, horizontal surface, but this resolution rapidly deteriorates to hundreds of yards as the surface gets rougher and tilted. David E. Smith, principal investigator on the instrument, believes the radar might realistically achieve a vertical resolution of around 50 feet over most of Mars. Smith said his team hopes to map Mars at least four times.

The radar should be able to see individual lava flows around volcanoes and determine which flows lie on top of others. Knowing which formed first, combined with already known crater counts, can give scientists a much better idea of how volcanic flows formed. Similar age measurements should be possible for individual ice sheets at the poles.

The radar will "illuminate" a 5.5-mile area of the Martian surface at a time. One hundredth of a second later the radar will illuminate another 5.5-mile circle, and because the spacecraft will have moved in that time, the new circle seen by the radar will be offset slightly from the first one. "We aren't quite sure how we're going to do this, even in our own minds," Smith says, but he believes it is "in principle" possible to use this offset to improve the horizontal resolution of the radar to as little as 2 miles.

As a microwave radiometer the radar will measure the electrical properties of the Martian surface. This information can be used to calculate the porosity, or gaps between rock and solid particles, and by inference the density of surface rocks and soil. It may even be able to detect the liquid water some scientists have suggested lies just under the sands of the Hellas Basin, provided the water lies very close to the surface.

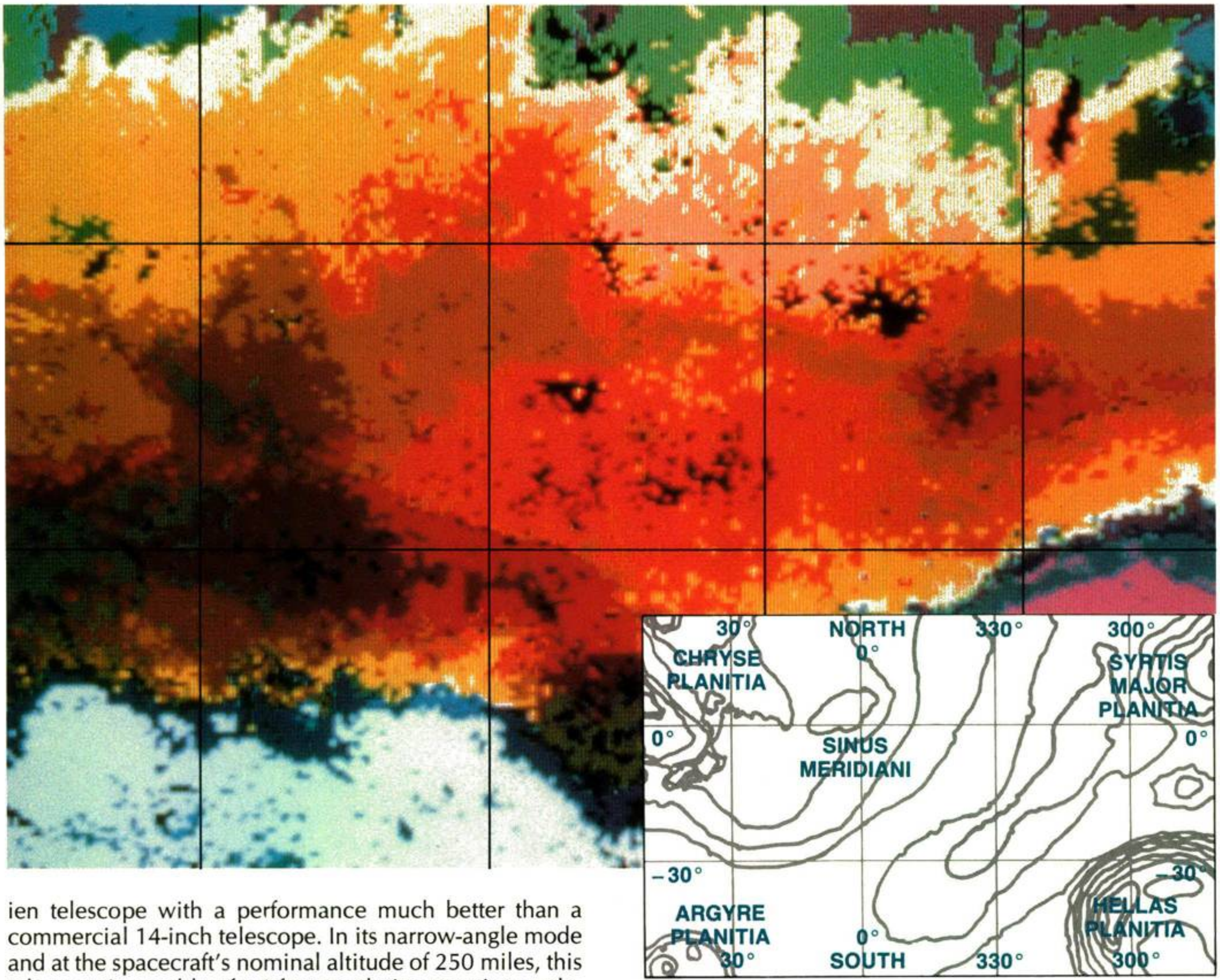
Low-resolution global images and very high-resolution images of selected areas are the goal of the *Mars Observer* Camera. Michael C. Malin of Arizona State University, principal investigator on the camera, intends to map the entire planet every day with an average resolution of just under 5 miles. By taking pictures through violet and red filters, the camera team can reconstruct color images that will separate ground-hugging fogs and high-altitude hazes from the surface features.

### Watching Martian Weather

"Our Martian weather maps will look like the weather maps of Earth we see every night on television," predicts Malin. In its wide-angle mode the camera will achieve a maximum resolution of 300 yards.

"This experiment was originally conceived to counter the argument that we have learned all we can from pictures of Mars," says Malin. Most important, however, is that "we don't know what we'll see. Every time you get a factor of ten better in resolution, you revolutionize your knowledge of Mars."

Malin described the high-resolution portion of the camera as a 3.5-meter focal length f/10 Ritchey Chret-



**Until the next Mars orbiters begin returning data, our most detailed view of the planet's surface composition comes from studies combining Earth-based and *Viking* orbiter data. This map of one fifth of the Martian surface shows compositional units in the morning hours of the northern hemisphere summer in 1976: frost (white), fine-grained dust (pink), and rock-derived soils (dark brown). Courtesy Thomas McCord, University of Hawaii.**

ien telescope with a performance much better than a commercial 14-inch telescope. In its narrow-angle mode and at the spacecraft's nominal altitude of 250 miles, this telescope is capable of a 4-foot resolution per picture element, or pixel. A typical narrow-angle photograph will be square and cover an area on Mars just under 2 miles across. It will be accompanied by a wider angle picture taken at the same time and in exactly the same direction to provide context.

By measuring boulders visible in these images, Malin hopes scientists will be able to tell once and for all whether the channels were formed by running water, by ice or mud flows, or by wind. The sizes, orientations, and distribution of boulders in the Martian channels are "diagnostic of the transporting medium," says Malin.

Malin and other scientists working on the Colorado Plateau in Utah and Arizona have developed a series of land-form criteria in the 3- to 6-foot size range they hope to use to determine whether the valley networks found in the ancient Martian highlands were formed by ground water sapping or by rainfall resulting in rivers.

Malin also hopes to be able to see the types of land forms characteristic of "fresh" volcanic action. Whether fresh means thousands of years or hundreds of thousands of years is immaterial: either would be considered evidence of "current" volcanism. However, unless scientists are lucky enough to image a volcanic eruption under way, the camera is unlikely to directly prove that Mars is still volcanically active.

The images taken by the camera will also be useful to future proposed automated sample-return or human missions to Mars. "Our resolution may be a little too low for safe lander images," says Malin, "but we're orders of magnitude better than *Viking*. If there were cars there, we'd be able to see them. One of the original objectives of this experiment was to see the *Viking* landers." Although the camera will now have slightly lower resolution than originally planned, imaging the *Viking* spacecraft on the ground should just barely be possible.

The Soviet *Vesta* mission, which includes an automated lander, is scheduled to be on Mars at the same time *Mars Observer* is orbiting the planet. "We may be able to actually see their lander at work," Malin says, "and they may want us to help them pick out their landing site."

By the time *Mars Observer* completes its mission, we will understand this dynamic planet in exquisite detail. Scientists will have determined the composition of Martian soil and bedrock, followed the rise and fall of global dust storms, and mapped the terrain of Martian volcanoes and valleys. In the process we will better understand the forces that shaped this planet and, as a result, come to understand our own planet better too.

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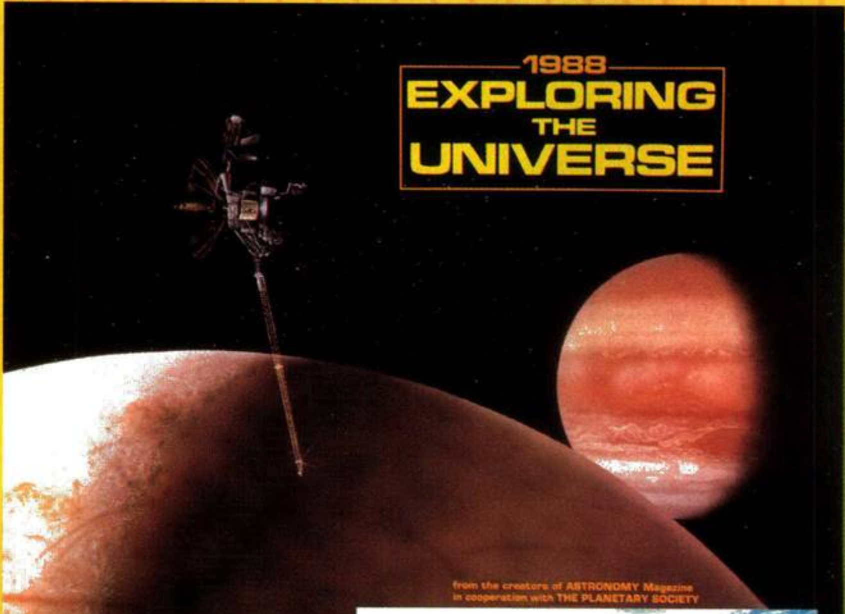
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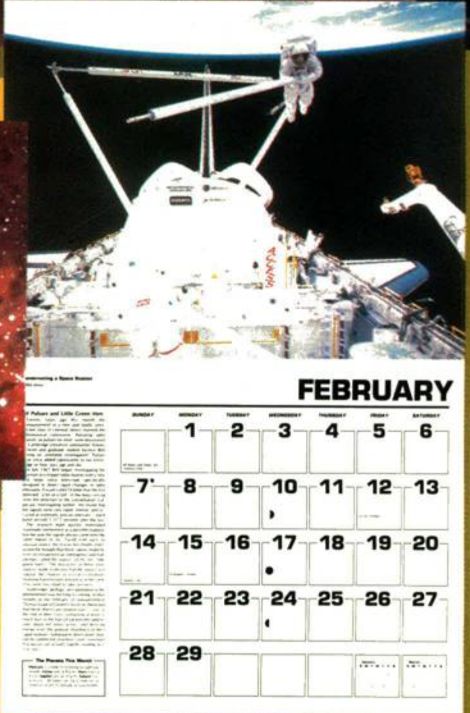

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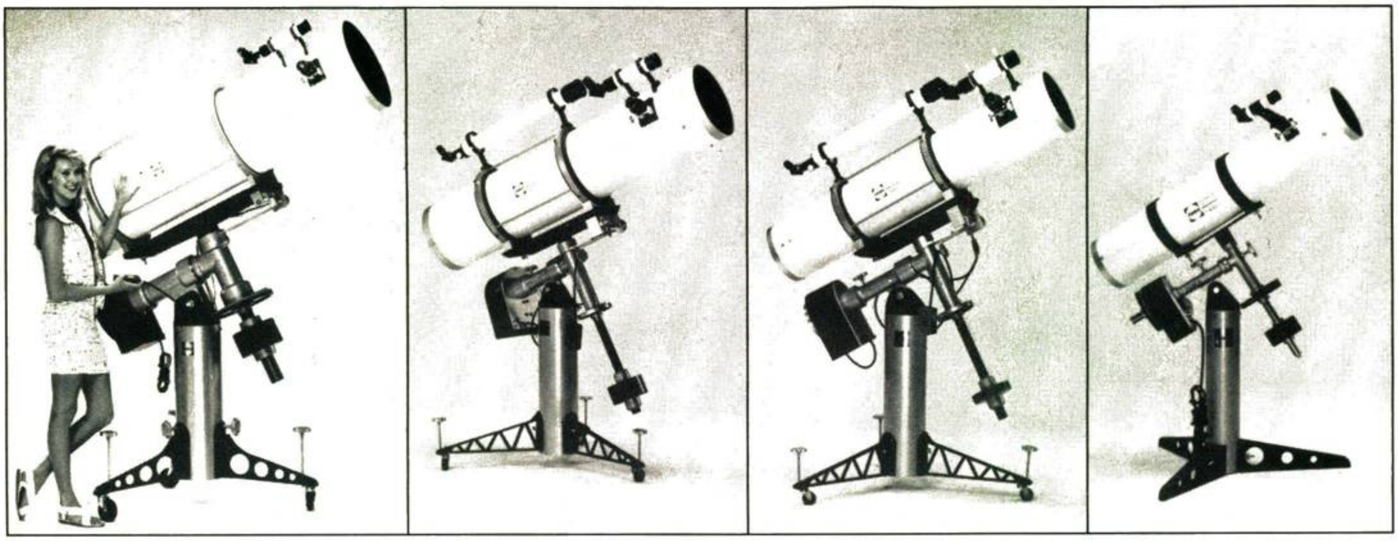

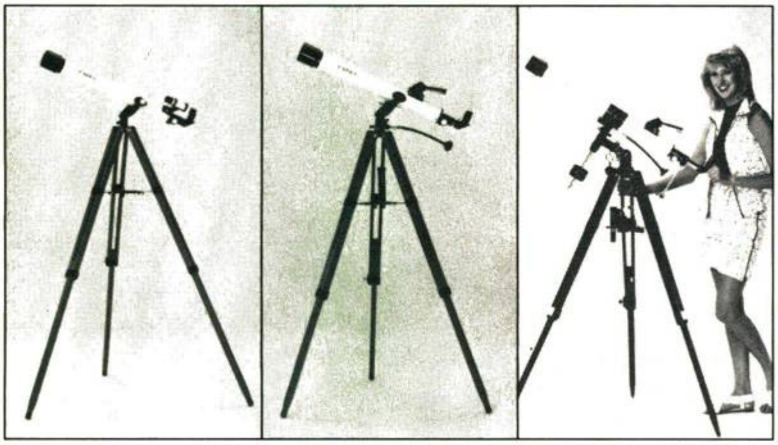

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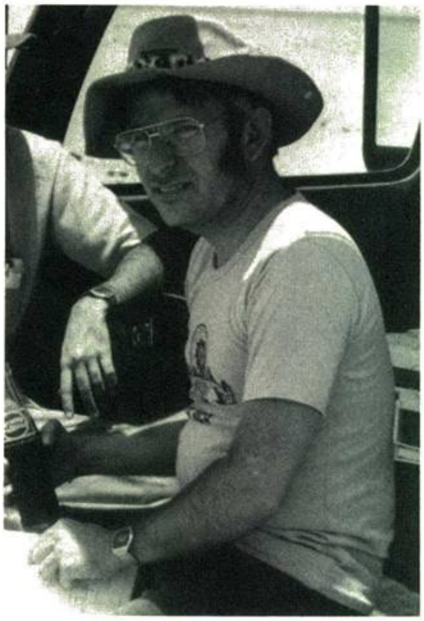
# ASTRONOMY Forum

## Globetrotting Observer Paul Maley: Chasing the Fleeting Moment



*Paul Maley is a veteran observer of unusual and transient celestial events. Through his association with the International Occultation Timing Association (IOTA) and the Hanssen Tours Agency in Houston Maley has led dozens of trips to all corners of the globe to observe satellites, lunar and asteroid occultations, and solar eclipses.*

*Maley participated in the Smithsonian Astrophysical Observatory's Moonwatch optical satellite tracking program in the 1960s. He is also a pioneering observer of asteroid occultations as well as the new field of possible satellites of asteroids. Today he works as an engineer at the Johnson Space Center in Houston, Texas.*

ASTRONOMY: When did you first sink your teeth into astronomy?

Maley: I got interested when I was about eight or ten, probably while I was watching the television coverage of the first *Vanguard* satellite rockets in 1958. When I was in fifth grade, a neighbor set up a home-built plywood telescope in his driveway. I got to look through his telescope, and at that point I was hooked.

Because I'm interested in observing unusual transient phenomena though, I'm actually more of a transient phenomena specialist than an amateur astronomer.

ASTRONOMY: In the past twenty-five years your astronomical interests have included satellites, novae and comets, astrophotography, and lunar and asteroid occultations. Where are you headed now?

Maley: I concentrate on making observations that can be used by professional scientists, which is why I observe one-time transient events.

ASTRONOMY: How involved were you with the Smithsonian Astrophysical Observatory's Moonwatch satellite observing team?

Maley: I made several thousand observations, both optical and positional, from San Antonio and Edinburg, Texas, over ten years. I used everything from the unaided eye to a 5-inch Apogee scope and measured the positions on *Bonner Durchmusterung* star charts.

ASTRONOMY: Did you see anything unusual?

Maley: Back in the Moonwatch days I observed the *Echo II* balloon during the first few revolutions in orbit where I could see the inflation process.

I also observed a couple of orbital breakups, which were terrific because I could see the pieces coming down in a stream.

It was also fun to watch the Russian *Molniya* satellites out at 7 to 10,000 miles. Those observations really pushed the limits of the 20-power 5-inch refractor I was using.

I specialize in observing Soviet spacecraft, and in 1986 I found evidence of a tether experiment. I've also discovered a correlation between satellite flashes and the Ogre, an optical gamma-ray emitter, which has been claimed to be a source of mysterious flashes of light.

Some of my data have been used to develop reflectivity characteristics that were important in the rendezvous and retrieval of the disabled *Westar* and *Palapa* satellites in 1984.

ASTRONOMY: What was the smallest satellite you've observed?

Maley: *Vanguard 1*. It is only 6 inches in diameter.

ASTRONOMY: What is the most distant Earth satellite you observed?

Maley: Other than translunar manned *Apollo* spacecraft, *Geostationary Operational Environmental Satellites* — 22,300 miles out. I've tried to see the various *Explorer* satellites like the *IMPs*, which travel much farther out, but the prediction data for them are poor and I haven't found them.

ASTRONOMY: You were one of the first qualified and trained observers to view the predicted re-entry of a decaying satellite. What impressed you most about that event?

Maley: I had no instruments to make any measurements. Back in those impoverished days I used to receive "re-entry telegrams" on a weekly basis. One hundred percent of these telegrams ended up in the trash because none of the predictions ever came true. But in 1967 when I received a telegram that said *Cosmos 166* was coming down, I decided just for the heck of it to go outside, sit on the steps, and look.

Soon I saw what appeared to be an aircraft light coming up from the south

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over Mexico. As I sat there, the light started to pick up brightness. Suddenly it developed a tail and I knew what was happening. I was sitting there with nothing, just a pad and pencil! I ended up drawing a sketch of what I saw.

ASTRONOMY: I understand you were one of the few eyewitnesses to the explosion in the command module of *Apollo 13* between the Earth and the Moon. How did you see it? What did it look like?

Maley: I came up with some look angles and was able to get an idle 16-inch telescope at the Johnson Space Center trained on *Apollo 13*. At the time we were really looking at the Saturn IV-B, the third-stage rocket booster, and knew *Apollo 13* must be in the vicinity. We kept seeing the intermittent flashes from the Saturn IV-B on the TV screen. Then suddenly we saw this image about the size of a quarter. That was the explosion of the oxygen tank, though we didn't know it at the time. Later we called the Mission Evaluation Room and found out that indeed there was a problem.

ASTRONOMY: Until the *Challenger* disaster you pursued re-entry observations of the space shuttle orbiters. What was the purpose of these observations?

Maley: There had never been any organized observations of manned U.S. hypersonic reusable vehicles during re-entry. This gave us a laboratory situation where the re-entry process, similar to meteor re-entries, could be studied. Except here, theoretically, the object being studied didn't disintegrate.

We discovered several things from shuttle mission 51-A. Many people, including people at NASA, thought that the space shuttle's sonic booms from 250,000 feet and up could not be heard on the ground. We proved that wrong.

Another phenomenon we discovered accidentally was the chemiluminescent wake that trails the orbiter during re-entry. We were able to show that as the shuttle re-enters, we see a channel in the atmosphere where the orbiter causes reactions with the nitrogen and oxygen atoms. Because of these reactions we saw a luminiscent column that persisted for nearly two minutes, similar to the high sky brightness seen in eastern Europe after the Tunguska explosion over Siberia in 1908. We could actually see vortices in the higher density areas of the trail.

We also found a double fireball effect caused by the re-entry shock.

ASTRONOMY: What sort of instruments have you used for observations?

Maley: I still own my original 5-inch Moonwatch Apogee scope. It's one of the best instruments I've used. I also have a pair of beat-up Tasco 7x35 binoculars that have been run over twice by my car (they work surprisingly well!). I have a 17.5-inch Dobsonian, 6-inch refractor, Celestron-8, and a briefcase-size break-apart 5-inch refractor I've used all over the world. I also have a pair of extraordinary 25x150 Fujinon binoculars with which I hope to discover a comet.

ASTRONOMY: How many foreign astronomical expeditions have you been on?

Maley: I'd guess around twenty. I've been to fifty-eight nations, but as for countries I've traveled to specifically to do observations, I think about twenty-five. Recently I did satellite observations from China, Pakistan, Austria, and Germany — all on one trip!

ASTRONOMY: What is the advantage of traveling to a foreign country to observe a satellite that will eventually pass over the United States?

Maley: They don't always, as in the case of *Geostationary Operational Environmental Satellites* located above longitudes on the other side of the Earth.

ASTRONOMY: How many solar eclipse expeditions have you led?

Maley: Nine: Canada in 1970, Georgia in 1972, Mexico in 1973, Colombia in 1977, Canada again in 1979, Africa in 1980, Indonesia in 1983, New Guinea in 1984, and Gabon in 1987.

ASTRONOMY: Which of your observations was the most difficult?

Maley: There are two I can think of. One was the occultation by the asteroid Lucina in 1982 at Lyon, France. I flew directly from Houston to France, not knowing what the weather would be like and without contacts in France waiting for me. I ended up hiring a taxi for the outrageous sum of $100 when I got there.

It was kind of funny, because when I got the taxi driver to stop at a dark spot on the road, I pulled out my briefcase and had this military-looking telescope I had put together in the dark. The guy looked at me as if I were a terrorist!

It was difficult because of thin clouds floating by, though I did make the observation at the critical time. But the prediction was off and I observed a miss!

ASTRONOMY: Does this mean the trip was wasted?

Maley: Yes and no. I wanted to see something, but the objective is also to see if there is evidence of a secondary occultation. There wasn't a secondary occultation, so at least I could report "negative" data, which is helpful.

The other difficult observation I made was the re-entry of the space shuttle external tank over Hawaii on mission 41-C in 1984. There were a lot of critical lighting conditions where a launch delay of only five minutes would have made my photography and video impossible.

In addition to that, the eruption of Mauna Loa volcano almost prevented us from reaching the ranger station at Mauna Kea where I needed the 9,500-foot altitude to view the tank re-entry's very low elevation.

I traveled to Hawaii to photograph the re-entry, but in the end I got much more: the re-entry, the eruption of Mauna Loa, and the track of the space shuttle *Challenger* as the shuttle ascended into orbit — all in the same picture!

This is the observation I'm most proud of. I got some spectacular color photos of the event, which appeared in *Aviation Week* and *Discover*.

Unquestionably, it was the most beautiful astronomical sight I have ever seen. It was a −6-magnitude object that turned into maybe twenty-five to thirty blue-green fragments that just seemed to hang there and float, tumble, and glide. This lasted for over two minutes. It was an incredible sight happening over an erupting volcano!

After it was over and near sunrise, we were driving back down the mountain, passing the 4,000-foot level, when we descended below the smoke from the forest fires that had been started by the lava. We could actually see the rivers of lava flowing from Mauna Loa.

At that point I looked up and saw one silver-blue cloud lying along the same track as the re-entry. I realized later that this was the aluminum residue from the tank suspended fifty miles up in the air.

I've also been lucky with observations. One I am proud of was a 1979 occultation by the asteroid Metis. When I got to the hotel in Georgetown, Guyana, I found out there was so much crime that going anywhere at night was very dangerous, much less ten miles out a dark road where I had originally planned to do the observation.

So I decided to make the observation from the roof of the Guyana Pegasus Hotel, knowing there was a good chance I wouldn't see anything. Despite heavy rain earlier that night the sky cleared up in time, so I set up my C-90, pointed at the star, and ended up getting a very long occultation! I obtained the first photograph, as far as I know, of an asteroid occultation in progress.

Another more recent case was when we were in the Sudan and encountered a violent sandstorm during the May 4, 1985, total eclipse of the Moon. We had to tear down our equipment and run for cover to our car, which was being rocked by the winds and big blops of sand that were being blown against it.

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Then about fifteen minutes before a grazing occultation began, the clouds cleared and we had the blackest skies I had seen in God knows how long. We ended up getting some very useful observations that may give us the most accurate measurement to date of the polar diameter of the Moon when the observations are finally reduced.

ASTRONOMY: What kind of personal experiences have you had in your adventures?

Maley: It's gone all the way from being accosted by an anti-American student in India, to having three astronauts participate in my occultation expeditions, to showing Greg Jarvis (who died aboard *Challenger*) how to observe Halley's Comet.

ASTRONOMY: How are you able to travel so much to pursue your observations?

Maley: Well, this year for instance, I had to take off two-and-a-half weeks from work without pay because I didn't have enough vacation time. Also, I don't have a family. I have the interest, zeal, and capability to do these things now, so I am going to do them. I'm not going to have any regrets twenty years from now wishing I had done this or that.

ASTRONOMY: Have any scientific discoveries come from your observations yet?

Maley: The observation that remains a big mystery now is the apparent secondary occultation I observed in conjunction with the 1977 occultation of Gamma Ceti by the asteroid Hebe.

ASTRONOMY: This is when you first became interested in satellite phenomena of asteroids?

Maley: Yes, that was what set it all off. The target star was enormously bright, magnitude 3.6. There was no question that it was eclipsed by something for a fraction of a second. The primary occultation was observed in Mexico City, nine hundred miles to the south. During the later data reduction I noticed that my observation occurred at almost the exact second as the primary occultation.

I was convinced I had seen this thing, so I called David Dunham of IOTA and we discussed it. Then I suggested a natural explanation, and the satellite theory sprang from this discussion.

We recognized this was very controversial, so we tried to present it as a phenomenon that has been observed. We felt that astronomers should start to watch more closely for evidence of similar events during future occultations.

After this the number of successfully observed events began to skyrocket for a time as people began to look at asteroid occultations. As a result we have a number of secondary events being observed by amateurs and professionals in many countries over the past ten years.

I hope to have a *Hubble Space Telescope* proposal approved to solve this lingering mystery.

ASTRONOMY: You wrote a story for ASTRONOMY about how the shape of Pallas was established by amateurs. (See "Measuring the Shape of an Asteroid" by Paul Maley, Equipment Atlas, February 1984). You organized the Texas observations of the 1983 Pallas occultation, didn't you?

Maley: Yes, that was probably my most difficult organizational work yet. Between phone calls, visits to sites, maps, and coordination meetings over the course of a year, it probably took several hundred man-hours.

We had a once-in-a-lifetime opportunity with Pallas, but we lost almost half of the Texas ground sites to clouds generated by a Pacific coast hurricane. We collected data for the entire northern hemisphere of the asteroid, but we lost much of the data for the southern hemisphere, which was a little disappointing.

I think we did prove you can take observations made by amateurs and come up with an orderly, uniform pattern. It's very important that amateur observations are handled professionally, and that amateurs are able to contribute to professional research studies. This fosters interest and encourages more people to get into amateur astronomy. That's what it's all about!

ASTRONOMY: What do you consider to be your crowning achievement in astronomy?

Maley: I don't think I've gotten there yet. I still want to discover something. Discovering a comet, for example, is something worth going for.

ASTRONOMY: How long have you been at the Johnson Space Center and what do you do?

Maley: I've been there seventeen years. I'm involved with the integration of Air Force payloads onto the space shuttle. Before that I worked as a space flight controller for seven years on various shuttle flights and *Skylab* re-entry.

During *Skylab*'s final days I occupied the Apollo Telescope Mount *Skylab* computer officer position. We were attempting to control the attitude of the craft to produce a controllable re-entry by monitoring the telemetry from this abandoned spacecraft.

During the *Skylab 4* mission in 1974 I advised mission controllers on the proper techniques of taking observations of Comet Kohoutek and plotting the magnitude forecasts, correcting for instrumentation factors, to see if the comet was getting as bright as predicted.

ASTRONOMY: How do you see the role of amateur observers changing in the increasingly high-tech world of astronomy of today?

Maley: I think the development of permanent infrared space observatories will endanger amateur comet hunters because these observatories will find new comets before we have a chance to pick them up. The *IRAS* observatory, for instance, picked up Comet *IRAS*-Araki-Alcock before the amateurs did.

But there is still plenty of room for amateurs, though their role is sort of dependent upon key organizations like the IAPPP, AAVSO, IOTA, and ALPO, which are geared to specific research programs that take advantage of the capabilities of amateurs.

ASTRONOMY: Just what steered you toward devoting so much of your life to astronomy?

Maley: I'm dissatisfied with the normal routines in life, and I'm curious about things. When you get hooked, you just keep going. Seeing the things there are to see in the universe creates a major high; all you have to do is go out and look!

I think that if an observation is important from a research standpoint, you should try to do everything possible to make the observation. If that means a little hardship for me, well, that's my own choice. You have to give up something in order to get something.

ASTRONOMY: Do you have any advice for people entering amateur astronomy?

Maley: You have to make the decision about whether to be a passive observer or to get involved in active research programs where you have to make personal sacrifices.

Some people think we must be crazy to go out late at night, perhaps driving for miles in inclement weather to make an observation that may last only a few seconds. But it's worth it. The experience of observing an occultation, a comet passage, or an eclipse is rewarding.

Many of the people who have been on expeditions with me have had very positive and sometimes emotional reactions.. For example, in Switzerland in 1984 a flock of people was outside the hotel early in the morning, standing on the shore of Lake Geneva, watching the space shuttle as it passed overhead at −4 magnitude. People were jumping up and down and yelling.

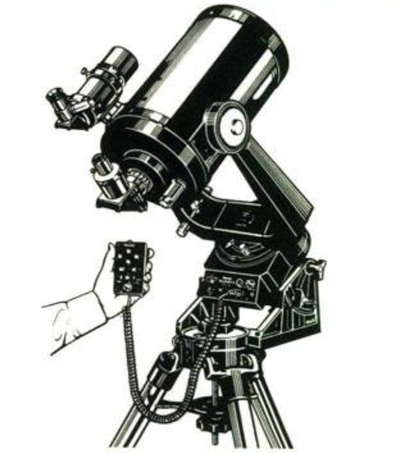
If you can translate what you do as an amateur astronomer through observations and show the unusual things in the universe to other people so they can enjoy them, it's all worthwhile. It's my way of returning to other people what I'm getting out of this.

— *Robert Reeves*
San Antonio, Texas

# MEADE EYEPIECES ARE WORTH A 2ND LOOK!

We would like to thank all of our customers for their support and enthusiasm. We will continue to provide you with the service and variety of product that is the policy of Northern Sky Telescopes. This month we have chosen to highlight the Meade Series 4000 Eyepieces with some specials that I think you will like. Don't forget we are still accepting entries for the drawing of the free Meade 2080 LX-5 until Sept. 30th, 1987. Good luck to everyone that has entered.

Jon Chase



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# ASTRONOMY In Focus

### Mars Mania in '88?

Sir / Amateur and professional astronomers now have a golden opportunity to capitalize on a celestial event that will make astronomy front page news in 1988, as Halley's Comet did in 1985-86. That celestial event is the opposition of Mars in September 1988.

Now is the time to begin a publicity campaign through astronomical groups, magazines like ASTRONOMY, observatories, manufacturers, and radio and television stations. This campaign and public observing sessions would promote astronomy to the public and resurrect interest in space research and exploration.

Mars is an excellent choice for a publicity campaign. The planet will have a number of favorable features as a telescopic object next year: color, changing detail, relative size, convenient observing time periods, and location in the sky. Mars has significant history both in astronomical and literary terms, which would add spice to written and broadcast articles on the planet. (This opposition will occur during the fiftieth anniversary of the *War of the Worlds* broadcast by Orson Welles on October 30, 1938.)

Mars has been explored by unmanned spacecraft, so an enormous quantity of photos and scientific data would add to the pool of information available to astronomers for program material on the planet.

Two years ago Halley Hoopla hit the general public. Now we can look forward to Mars Mania in 1988!

Dennis Sopchack
President, Kiski Astronomers
New Kensington, Pennsylvania

### Indiana's Sun Time

Sir / Contrary to the letter written by S. W. Bieda, Jr. (In Focus, August 1987), Arizona is not the only state in the contiguous United States that does not observe daylight saving time. In Indiana we also remain on standard time throughout the year, because we lie on the western edge of our time zone and the Sun sets late relative to New Jersey and Maine.

Bruce Bowman
Clayton, Indiana

### *Norton's Star Atlas* — for Today's Amateur?

Sir / Robert Burnham's review of *Norton's Star Atlas* (Astronomy Reviews, June 1987) was both arrogant and disrespectful.

The offense lay in Mr. Burnham's failure to see the book in the context it was written: *Norton's* purpose was to aid, guide, and instruct those who wished to learn about astronomy in an age when amateur astronomers were satisfied with and thankful for the knowledge they could get.

According to Mr. Burnham, we British astronomers must be terribly backward because we are not using what he calls "large-aperture Dobsonian light-buckets." May I remind him that neither were the Americans, and only modern (post-*Norton*) technology allows amateur astronomers to use them now.

Mr. Burnham calls the section of the book on mountings "woefully inadequate." This statement did little justice to the author's respectable decision to aid the practical amateur astronomer and save him money as well — not everyone can afford the best stand for his scope.

*Norton's Star Atlas* was not written for the 1980s breed of advanced astronomer, and Mr. Burnham's cutting way of poking fun at *Norton's* is not appreciated.

Richard Connor
Merseyside, England

*— Robert Burnham responds: Mr. Connor and I are talking at cross purposes. He accuses me of insufficient respect for a venerable monument of amateur astronomy, while I was trying to assess the value of that monument for today's backyard astronomers, particularly those in North America.*

*After all, if* Norton's *isn't written for the amateur astronomer of the 1980s, why on Earth should anyone today spend $30 on it?*

### Long Island Observers Need Permits Too

Sir / Lee Paulsel's letter (In Focus, August 1987) prompted me to write about the plight of amateur astronomers on Long Island, New York.

Not only do we need permits to stargaze in our state parks after dark, but now the Long Island State Park and Recreation Commission has decided to refuse us access to observing sites in state parks from January 1 through May 31, beginning in 1988. In New York these are the months of the best sky transparency and the sky contains those magnificent winter objects we wait all year to observe.

The parks commission offered us a light-polluted area in one of the parks after we rebelled. But a light-polluted observing site is no observing site at all.

After taking away *our* parks and *our* skies, what's next?

Jo-Ann Tompkins
Bayshore, Long Island, New York

### Don't Pelt Me with Bad Eyepieces!

Sir / Peter Wilson's letter (In Focus, June 1987) asked why ASTRONOMY can't stick to observing.

Different readers find different subjects interesting. *I don't* own a telescope or a pair of binoculars, but I can see plenty just with my eyes. Articles on what I can see with a 12-inch reflector are interesting reading for me — that's all. I don't observe those objects.

I find trying to come up with a logical model of how galaxies get their spiral shapes, what powers quasars, or even how NGC-5128 got that dust lane much more thought-provoking than looking at Polaris, which doesn't change much from minute to minute.

(I can picture myself being chased down the street by a bunch of irate observers screaming, "Traitor! You'd rather think than look?," and pelting me with bad eyepieces.)

Those of you who look and enjoy, please be tolerant of those of us who think and enjoy.

Cindy Cline
Winters, California

### Preserving the Night Sky

Sir / Peter Ceravolo's article "In the Glare of the New Moon (Forum, May 1987) was chilling. Are we the last astronomers? What a prospect for our children: Growing up in an environment of plastic and steel beneath a sky filled with artificial moons.

The implications of the great divorce between man and nature are too terrible to contemplate, but contemplate them we must if we are to avoid the spiritual destruction of humanity within the next thirty years.

The United States and the Soviet Union may very well place huge mirrors in Earth orbit that would illuminate cities, and the time has come to stop such madness before it becomes reality. If there is ever another U.S./U.S.S.R. summit, this exploitation of space should be discussed. The night sky belongs to everyone and must be preserved for all times.

David A. J. Seargent
The Entrance, New South Wales,
Australia

### Noctilucent Clouds Dazzling in Alberta

Sir / Thanks for the fascinating article on noctilucent clouds ("The Clouds of Twilight" by David McConnell, Gazer's Gazette, July 1987). I live in Calgary, Alberta — prime NLC territory — and was lucky enough to see a dazzling display of the phenomenon less than a month after I read about these mysterious clouds in your publication. The display was every bit as impressive as a good show of the northern lights.

Mark Oldfield
Calgary, Alberta, Canada

### Drawing at the Telescope

Sir / In "Tips for Shooting Clusters and Nebulae" by Matthew F. Willson (Photography in Astronomy, August 1987) the author implies that observing and drawing objects are passive activities compared to astrophotography.

I've been drawing objects since I began observing, and I draw every time I go to the telescope. I approach my drawings as scientific illustrations. When you're preparing for a drawing, proper eyepiece and magnification selection are as important as lens and film selection. Too little power and the delineation of details can't be made out, too much power, and contrast and form in extended objects like nebulae are lost. A realistic drawing also requires proper paper selection and drawing technique, refined from hours of experience at the telescope and practice away from the telescope.

Drawing astronomical objects also requires knowledge of the objects to be observed and rendered. An understanding of galaxy classification is helpful for spotting and identifying galaxies. Understanding the relation between magnitude and size is also useful.

If you think guiding for sixty minutes is tough, try a detailed drawing of M-42 for 90 to 120 minutes, carefully plotting star positions and capturing fleeting details.

As with most endeavors, skill and hard work produce quality results. This is true of astronomical drawing and, I'm sure, of astrophotography as well.

Michael Sweetman
Tucson, Arizona

### Oops!

The photograph of Cygnus on page 58 of the August 1987 issue ("Tips on Shooting Clusters and Nebulae" by Matthew Willson, Photography in Astronomy) was shot on hypersensitized Fujichrome 400, not on Tech Pan as reported in the article.

Behind the Scenes

## It's a Planet, by Jove!

Have you seen Jupiter this year? If you haven't, it's worth braving the cold to see. Jupiter is near perihelion at opposition this year, so it is closer, bigger, and brighter than it's been in the last twelve years — and that makes a big difference in how much detail you can see on the planet. Jupiter, in case you aren't a regular observer, now rises at sunset and is visible all night.

Why the emphasis on Jupiter? Last year we were impressed with David Lindemann's observations of a new large blue festoon (see In Focus, November 1986). Using an ordinary 6-inch reflector, he noticed a new blue feature in the North Equatorial Belt. This year we invited Jose Olivarez of the Association of Lunar and Planetary Observers and a lifelong Jupiter observer to write on observing the Giant Planet so all of ASTRONOMY's readers could see what a fascinating planet it is.

"What I like most about observing Jupiter," says ASTRONOMY assistant editor Jeff Kanipe, "is that things happen, sometimes on a nightly basis. The belts and zones on Jupiter show off ever-changing loops, arches, and festoons." Jeff worked with Olivarez to prepare this month's Gazer's Gazette for publication. In my own observing lifetime I've seen Jupiter's Great Red Spot darken to brick red and fade to pale pink. It's an entire world — restless and dynamic — just waiting for you to watch. The story begins on page 64.

This summer the planets Saturn, Uranus, and Neptune also put on a fine show. Saturn was a magnificent sight with its rings tipped wide open. Neptune lurked just 5° east of the Lagoon and Trifid nebulae, and Uranus shone an unmistakable green just 4° west and a degree north of the nebulae. (Even deep-sky observers had no excuse for not finding Uranus and Neptune this year!) If you didn't see *Voyager*'s last three planetary targets this year, be sure not to miss them next year.

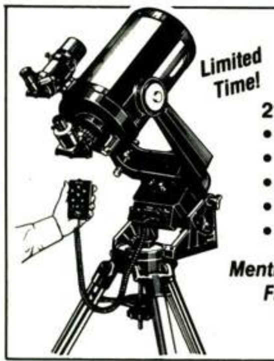
Meanwhile, we'd like to remind you to get ready for Mars. Opposition occurs on September 27 next year, when the Red Planet is near the celestial equator and close to perihelion. This means Mars will show observers a large disk — the largest in seventeen years — and will be well placed for those of us in the Northern Hemisphere. I hope you're looking forward to Mars in '88 as much as I am.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

# MEADE SUPER SALE!



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1. To enter, complete and mail the ASTRONOMY MAGAZINE SWEEPSTAKES OFFICIAL ENTRY FORM (enclosed in this magazine) or a facsimile. Be certain that your name and address are listed correctly. You need not subscribe to ASTRONOMY to be eligible to win. No purchase necessary.
2. Entries are limited to one per-person per-month. To be eligible for monthly prize awards, entries must be postmarked by the final day of the preceding month (i.e., November 30 for the December drawing). Monthly prizes will be selected in December 1987, January 1988, and February 1988. All entries must be postmarked by January 31, 1988. The grand prize will be awarded in February 1988. Monthly prize winners will become ineligible for future monthly awards, but will be eligible to win the grand prize. All entries qualified under these rules will be eligible for the grand prize.
3. Winners will be selected in random drawings and decisions are final. Winners will be notified by mail and/or telephone. Any prizes returned as undeliverable will be awarded to alternate winners. Chances of winning are determined by the total number of entries received.
4. Taxes on prizes are the sole responsibility of the winners. No substitutions will be made for any prize offered. All prizes will be awarded.
5. Sweepstakes is open to residents of U. S., and Canada. Employees and stockholders of Kalmbach Publishing Co., and their families are ineligible. Sweepstakes is subject to all Federal, State, and local laws and regulations and is void whenever prohibited by law.
6. Selection of equipment and accessories subject to product availability. Grand prize winner will select his/her choice of products from advertisements placed in the November 1987, December 1987, and January 1988 issues of ASTRONOMY. The winner of the December 1987 1st prize drawing will select products from ads appearing in the November 1987 issue. The winner of the January 1988 1st prize drawing will select products from ads appearing in the December 1987 issue. The winner of the February 1988 1st prize drawing will select products from ads appearing in the January 1988 issue. Value of all products awarded in Sweepstakes will be established at manufacturer's/importer's suggested retail price.

For a complete list of winners, send a self-addressed, stamped envelope to: ASTRONOMY Magazine Sweepstakes Winners, 1027 N. 7th St., Milwaukee, WI 53233.

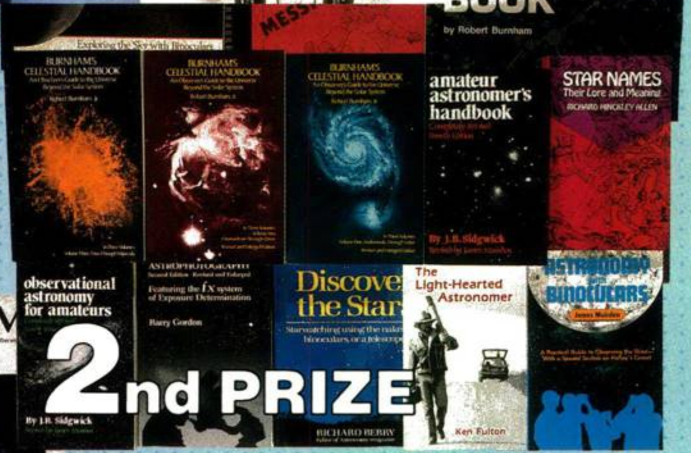
# PLUS, these valuable prizes presented each month through February 1988!

1st PRIZE
Bushnell

**$500 in your choice of astronomical products!**
*1 prize each month*

### A Complete Library of Astronomy Books
*2 prizes each month*

**BOOKS: Leslie Peltier's Guide to the Stars • The Light-Hearted Astronomer • The Star Book • Amateur Astronomer's Handbook • Astronomical Companion • Astronomy with Binoculars • Astrophotography • Burnham's Celestial Handbook, Vol. 1 • Burnham's Celestial Handbook, Vol. 2 • Burnham's Celestial Handbook, Vol. 3 • Discover the Stars • Norton's Star Atlas • Observational Astronomy for Amateurs • Star Names: Their Lore and Meaning • A Starhopper's Guide to Messier Objects • Uranometria 2000.0, Vol. 1**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THE STAR BOOK
by Robert Burnham
Exploring the Sky with Binoculars
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amateur astronomer's handbook
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observational astronomy for amateurs
ASTROPHOTOGRAPHY
Discover the Stars
The Light-Hearted Astronomer
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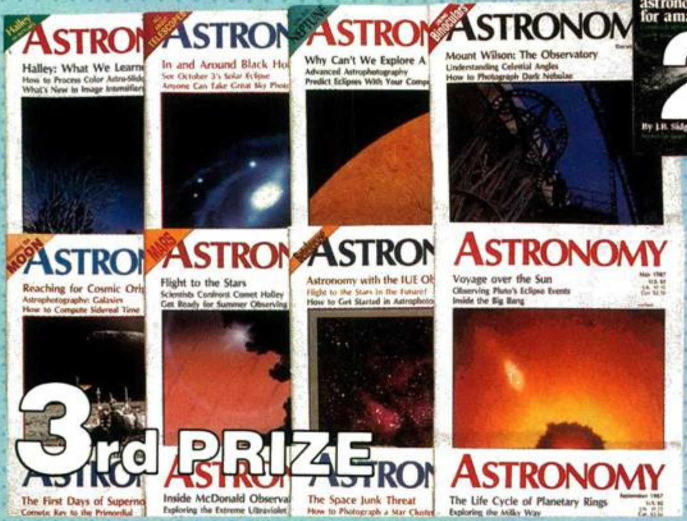
2nd PRIZE

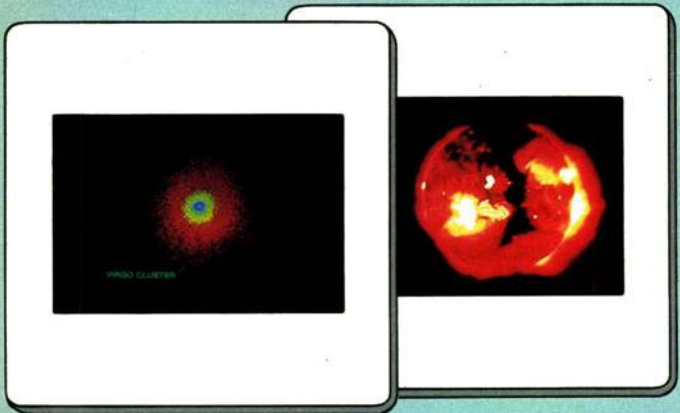

ASTRONOMY
3rd PRIZE

**A 5-year Subscription to ASTRONOMY Magazine!**
*3 prizes each month*

ASTRONOMY

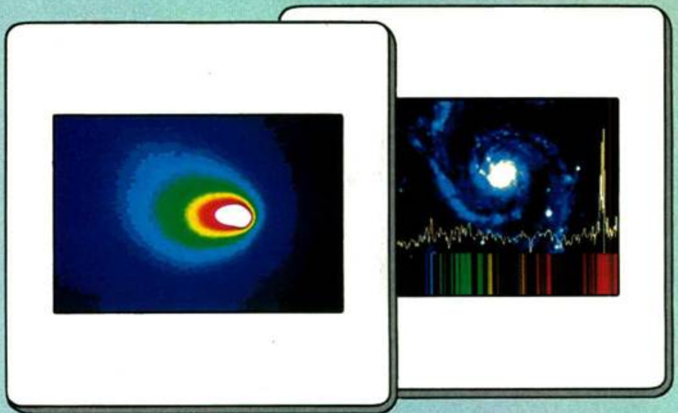
# Explore the Universe from Your Living Room

*These 6 sets of 35mm slides take you on spectacular voyages of discovery into the universe. From the comfort of your home, you can explore our Solar System, thrill to the wonders of the Milky Way, discover the latest in x-ray astronomy . . . and more! Each set includes a descriptive booklet.*



The first color photographs of deep space as seen in x-rays — here are supernova remnants, cosmic "bursters," black hole candidates, clusters of galaxies, and quasars! This set portrays the results of observations by HEAO-2, the Einstein Satellite launched in 1978. Produced in cooperation with the Smithsonian's High Energy Astrophysics Div. 56 slides (49 in color). #30147

**VISIONS OF 'EINSTEIN'** **$38.95**



These computer-processed images illustrate a sample of the new techniques now available to astronomers. Solid-state electronic light sensors and computers combine to produce unique and revealing images of the universe. Taken at the Smithsonian's Observatory in Arizona and reconstructed at the Harvard-Smithsonian Center for Astrophysics. 40 color slides. #30148

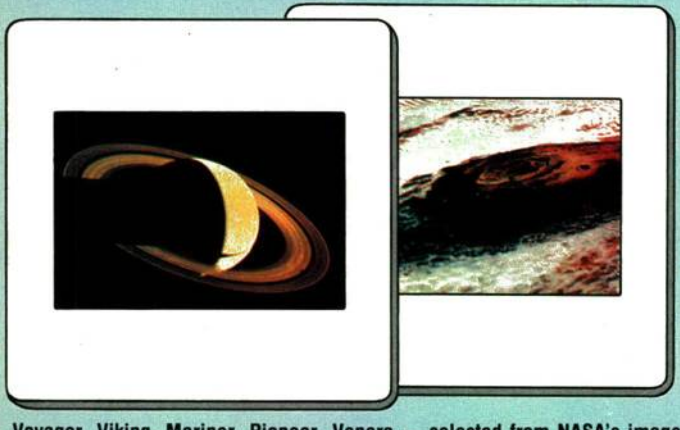
**THE ELECTRONIC SKY** **$31.95**

From its fantastic collection of dramatic space art, ASTRONOMY proudly presents this unique set. Tease your imagination with glorious deep-space vistas by renowned space artists including Adolph Schaller, Mark Paternostro, Rick Sternbach, and John Clark. 48 color slides. #18025

**ASTRONOMY SPACE ART** **$38.95**

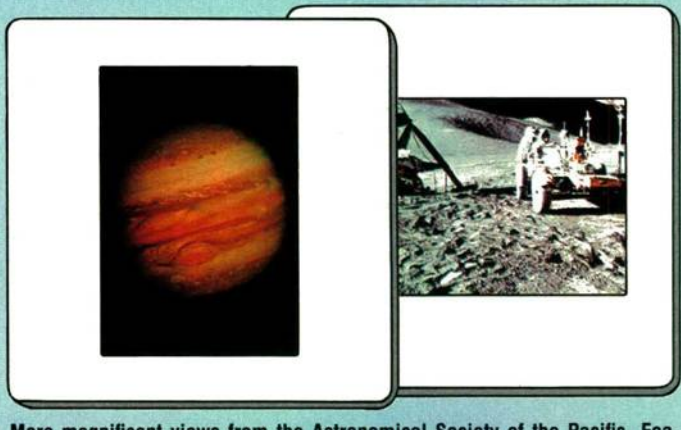
Under the dark skies of southern California and Australia, astrophotographer Rev. Ronald Royer employed special color separation techniques to record the delicate traceries of celestial gas and dust in our Milky Way Galaxy. The result is this fine set of 35mm jumbo slides. 60 color slides. #30105

**THE MILKY WAY IN COLOR** **$41.95**



Voyager, Viking, Mariner, Pioneer, Venera — selected from NASA's image archives by Dr. David Morrison, noted planetary scientist and president of the Astronomical Society of the Pacific, this set brings the new era in Solar System exploration right into your living room! 50 slides (24 in color). #30106

**SOLAR SYSTEM CLOSE-UP PART 1** **$39.95**



More magnificent views from the Astronomical Society of the Pacific. Features all new images (no duplicates with Part 1) and includes the Soviet color images of the surface of Venus, spectacular vistas of planet Earth, and the satellites of Saturn. 50 slides (25 in color). #30107

**SOLAR SYSTEM CLOSE-UP PART 2** **$39.95**

**SAVE! Order both Solar System sets for only $71.95!**

**To order, use the ASTRONOMY order form bound into this magazine, or send to ASTRONOMY Order Dept., 1027 N. 7 St., Milwaukee, WI 53233. Include for postage and handling: U.S. $1; foreign $1.50. Wisconsin residents add 5% sales tax.**

SOLAR SKREEN • ASTRO TULE • NO DU CAPS • SUPER FINDER • ULTIMATE FINDER • STEREOOCULAR

MICRO DRIVE • MINI MOUNT • SOLAR PROMINENCE PROBE • ISOSTATIC MOUNT • CELESTIAL NAVIGATOR

# YOUR ASTRONOMICAL FRIEND ANNOUNCES: THE TUTHILL ASTRO VIDEO SEMINARS. FIRST IN A SERIES OF INSTRUCTIONAL VIDEO TAPES ON BASIC ASTRONOMICAL EQUIPMENT OPERATION AND ASTROPHOTOGRAPHY by ROGER W. TUTHILL.

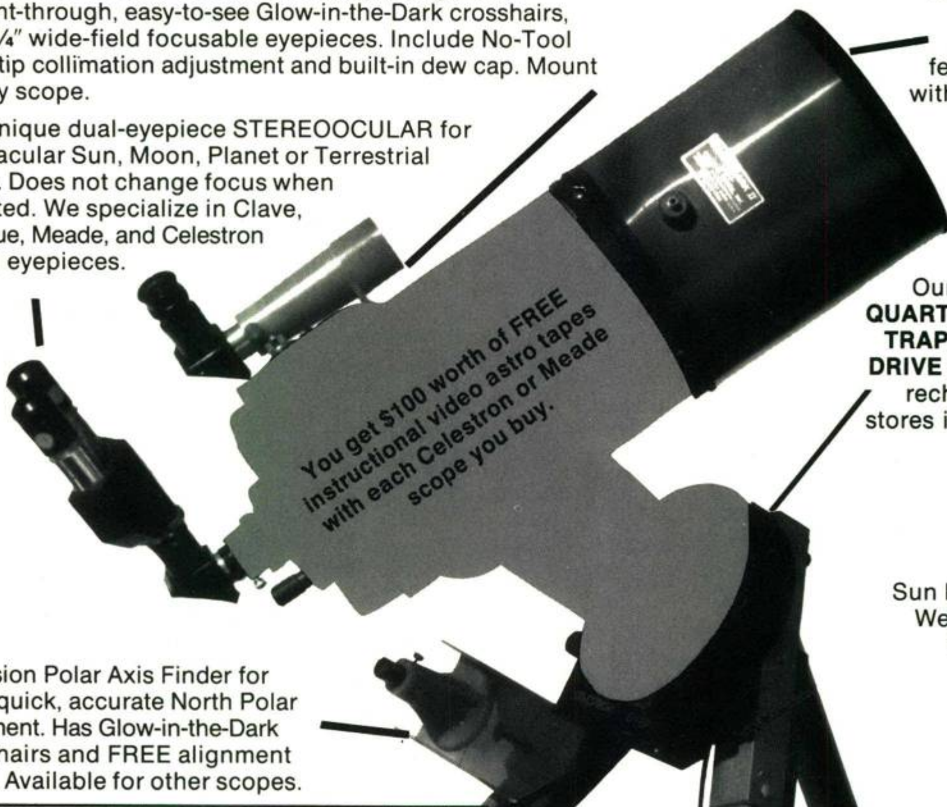
Some of the subjects covered are: short cuts in set-up, how to understand and use setting circles, how to get quick and accurate polar alignment, straight talk about eyepieces and hints on astrophotography. Designed for the beginner as well as the advanced amateur. The sequence on optical collimation alone is worth the price! Two tapes now available: #1 Basic SCT operation - $50., #2 Advanced SCT astrophotography - $50. Get both for only $80 and save $20. **BOTH TAPES *FREE* WITH EVERY MEADE or CELESTRON SCT WE SELL.**

**— These Video Tapes may be RENTED for as low as $20 each —**

Giant Finders, 50mm & 80mm diam. right-angle and straight-through, easy-to-see Glow-in-the-Dark crosshairs, use 1¼" wide-field focusable eyepieces. Include No-Tool fingertip collimation adjustment and built-in dew cap. Mount on any scope.

The unique dual-eyepiece STEREOOCULAR for spectacular Sun, Moon, Planet or Terrestrial views. Does not change focus when adjusted. We specialize in Clave, TeleVue, Meade, and Celestron Plossl eyepieces.

No-Du-Caps are lightweight, heated with moisture-absorbing features. Easily attach without tools for Meade 2080, 2120, C11 & C14 scopes.


You get $100 worth of FREE instructional video astro tapes with each Celestron or Meade scope you buy.

Our **NEW CORDLESS QUARTZ - LOCKED STAR TRAP POWER MODULE DRIVE CORRECTOR** with rechargeable batteries stores inside the C8 base.

SOLAR SKREEN® Sun Filters for all scopes. We sell hydrogen alpha filters for all scopes.

Precision Polar Axis Finder for easy, quick, accurate North Polar alignment. Has Glow-in-the-Dark crosshairs and FREE alignment chart. Available for other scopes.

NEW Knot-Free Redwood Isostatic Equatorial Mount. A combination wedge and tripod with built-in latitude AND height adjustment. Includes 3 No-Tool knobs and vibration-resistant pads. Lightweight, folds up for easy portability and storage. For any size Schmidt-Cass. scope, Meade 2045, 2080, Questar, B&L 4000, C11 and C14.

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LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices. Both Catalogues $3.

# LUMICON FOR HIGH PERFORMANCE

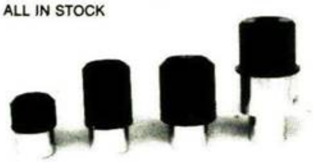
## ASTROPHOTO OF THE MONTH

**Spiral Galaxy M-33 in Triangulum.** This low surface brightness galaxy is seen best visually with a LUMICON DEEP-SKY Filter. Photo by Dr. Jack Marling using a LUMICON Newtonian EASY-GUIDER and 2415 film sensitized in a LUMICON Model 300 HYPER-KIT; 40 min. exposure, 10"f/5 telescope.

## 20mm NAGLER

**Also new 12mm & 16mm NAGLERS**
**TELE VUE™ EYEPIECES**
**USE THE BEST!!**

ALL IN STOCK



| | |
|---|---|
| Renaissance 4" f/5.5. Telescope | $1395 |
| **7.4, 10.4, 13, 17, 21, 26mm Plossl,** 50° | **$89** |
| **1.8X or 2.5X Tele Vue Barlow Lens** | **$89** |
| **32mm Plossl,** widest true field in 1¼" | **$109** |
| **55mm 2" Plossl,** widest possible field | **$190** |
| **15mm Wide-Field,** 1¼" eyepiece, 65° | **$129** |
| **19mm Wide-Field,** 1¼" eyepiece, 85° | **$139** |
| **24mm Wide-Field,** "superb," 65° | **$159** |
| **32mm Wide-Field,** 2" eyepiece, 65° | **$229** |
| **40mm Wide-Field,** "awesome," 65° | **$289** |
| **4.8mm Nagler,** 82° field | **$149** |
| **7mm Nagler,** 1¼" eyepiece, 82° field | **$185** |
| **9mm Nagler,** 82° field, "the best" | **$219** |
| **11mm Nagler,** 82° field, 1¼" or 2" | **$235** |
| **13mm Nagler,** 82° field, 1¼" or 2" | **$249** |
| **12mm Nagler,** type II, 82°, 1¼"/2" | **$249** |
| **16mm Nagler,** Type II, 82°, 1¼"/2" | **$299** |
| **20mm Nagler,** Type II, 82°, 2" only | **$340** |

### ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs. **LUMICON Adjust. Piggyback Mount .. $45**
Specify telescope size: 6", 8", 10", 11", 14", 16"

### H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photography with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) *Filter.*

| **Specify Lens Size** | **H-Alpha** | **(MV)** |
|---|---|---|
| 46, 48, 49mm | **$35.00** | **$29.00** |
| 52, 55, 58, 62mm | **$45.00** | **$35.00** |
| 67, 72, 77mm | **$52.00** | **$45.00** |
| 82mm | **$55.00** | |

Hypered 2415 film, 36 exp ... **$10.95 ... 3/$29**

## LUMICON®

**2111 Research Dr. #5A, Livermore, CA 94550**
**For phone orders please call (415) 447-9570**
**LUMICON Products catalogue $2.**
**Foreign orders add 6% ($8 minimum)**
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**Prices subject to change w/o notice**
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### NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

**LUMICON 1.3" & 2.1" enhanced silver diagonal mirrors & 1¼" star diagonal.**
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine an*nealed Pyrex flat to 1/8 wave*

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**
4.25" **$149.50**

### ENHANCED SILVER STAR DIAGONAL

*90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.*

1¼" (1.32" mirror) ........ **$89.50**
2" (1.83" mirror)(see photo above) .. **$145.00**

## LUMICON FILTERS STOP LIGHT POLLUTION

## UHC Filter™

### ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm. Transmission = 85-95%.

**"I CAN SEE THE VEIL NEBULA!"**
*Rich Zepernick saw the Veil Nebula for the very first time with a LUMICON UHC Filter. He stated, "It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
**Zepernick, Cresskill, NJ**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

### DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 85-95%. Visible transmission = 90-95%.

| | **Standard** | **Premium*** |
|---|---|---|
| **0.96" LUMICON DEEP-SKY Filter** threads into most 0.96" eyepieces | | **$59.50** |
| **1¼" LUMICON DEEP-SKY Filter** threads into most 1¼" eyepieces | | **$79.50** |
| **48mm LUMICON DEEP-SKY Filter** (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS | | **$119.50** |
| **2" LUMICON DEEP-SKY Filter** (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography | **$99.50** | **$119.50** |
| **72mm LUMICON Giant DEEP-SKY Filter** (62, 67, 77mm adapter, $8) | | **$299.50** |
| **1¼" LUMICON UHC Filter** threads into most 1¼" eyepieces | | **$99.50** |
| **48mm LUMICON UHC Filter** (1.75" aperture) fits most 2" eyepieces | | **$199.50** |
| Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%) | | **$159.50** |

**LUMICON H-BETA Line Filter** (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. ....... **1¼" $89.50** ....... **48mm $189.50**
**Oxygen-III Filter** for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm *0-III lines* .......... ***1¼" $99.50, 48mm $199.50***
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm.......... **$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece...... **$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece......... **$20.00**
**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

# DEEP-SKY ASTROPHOTOGRAPHY

### FILM HYPERSENSITIZATION KITS†

**LUMICON HYPER-KITS™** yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.
U.S. Patent 4,473,636

### MAKE YOUR OWN HYPERED FILM

**MODEL 300 HYPER-KIT** sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds ...... **$295.00**

**MODEL 600 HYPER-KIT** [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates ........ **$350.00**

**MODEL 1200 HYPER-KIT** is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller .. **$595.00**

Temperature controller for any HYPER-KIT ........ **$59.50**

Electric Vacuum Pump, Model R-10 **$280.00**

### GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

### NEWTONIAN EASY-GUIDER™

Full aperature. Installs in secs. Specify 2" or 1¼".
NEWTONIAN EASY-GUIDER ...... **$169.50**
3X Relay Diagonal (see photo) ..... **$79.50**
Illuminated reticle eyepiece system .. **$89.50**
Guider for Hasselblad **$350,** Mamiya 645 **$199**

### CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER ..... **$225.00**
Adapter for Hasselblad **$185,** Mamiya 645 **$159**

### GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**
GIANT EASY-GUIDER.............. **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)...... **add $99.95**
Adapter for Hasselblad **$195,** Mamiya 645 **$96**

### WHAT DO YOU NEED?

1. Illuminated reticle eyepiece ...... **$89.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. *Declination reverse switch for Newtonians.*
**Declination motor (state telescope) .. $70**
**NEW** Deluxe Digital Qtz. Drive Correc. **$298**

NEW
SRV3200

### HYPERSENSITIZED FILM

*LUMICON Hypersensitized film is essential for* good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

| **Film Type, 35mm** | **Exposures** | **Price** |
|---|---|---|
| 2415, Ultra-fine B&W, red sens. | 36 | **$10.95** |
| SRV3200, fastest of all, color neg | 24 | **$13.95** |
| Konica SR1600, very fast, fine gr. | 12 | **$12.95** |
| Konica SR400, fine grain color neg | 12 | **$10.95** |
| 3M 1000, fastest slide film | 20 | **$12.95** |
| Fujichrome RD100, fine grain slide | 24 | **$12.95** |
| D-19 B&W Developer | 1 gal. | **$6.95** |

# NEW LUMICON® PRODUCTS

LUMICON, 2111 Research Dr., #5
Livermore, CA 94550 (415) 447-9570

## NEW! NON-ROTATING HELICAL FOCUSER

**LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6'' telescope.**

LUMICON has just designed a deluxe smooth helical focuser with non-rotating 2'' i.d. eyepiece holder. It has a vertical travel of 1¼'' and a very low profile only 1½'' high. It is CNC machined, black anodized, and a perfect match to LUMICON EASY-GUIDERS.

**Select your desired base-plate shape!**
Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 20'' OD, SUPER-FINDER base plate.

| | |
|---|---|
| **LUMICON Deluxe Helical Focuser** ... | **$79.50** |
| 3 handles (see photo) ............... | **$12.95** |
| Helical focuser with 3 handles ....... | **$92.40** |
| **2''/1¼'' adapter** w/48mm filter threads | **$20.00** |
| **2'' LUMICON EASY-GUIDER** ....... | **$169.50** |

## EYEPIECE PROJECTION

These adapters allow high magnification photography of the Moon and Planets using eyepiece projection. They may be used without any eyepiece for prime-focus photography. All adapters use standard camera T-rings.

| | |
|---|---|
| Tele-Extender for Meade or Celestron SCT. | **$32** |
| 1¼'' Basic Camera adapter, 2 part system | **$32** |
| 0.96'' Basic Camera adapter, 2 part system | **$32** |
| 1¼'' prime Focus adapter, fits 1¼'' focuser | **$22** |
| 0.96'' prime Focus adapter, fits 0.96'' focuser | **$22** |
| Camera T-ring, specify 35mm camera type | **$12** |

## LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

| | |
|---|---|
| 1¼'' 50mm Finderscope **$59.50**, right-angle | **$89.50** |
| 1¼'' straight-thru 80mm SUPER-FINDER ... | **$169** |
| 1¼'' right-angle version, w/star diagonal .... | **$195** |
| 2'' right-angle version, non-rotating focuser .. | **$199** |
| 1¼'' Deluxe right-angle Super-Finder* ....... | **$279** |
| 2'' Deluxe right-angle Super-Finder* ....... | **$309** |
| 25mm Cross-hair 1¼'' eyepiece (12X) ....... | **$29** |
| *1¼'' Star Diag. **$32**, 2'' Star Diag., silver, | **$145** |
| 1¼'' Amici Prism diag. for correct left-right views | **$59.50** |

## 2'' ADAPTERS MEADE, CELESTRON TELESCOPES

These adapters convert refractors and Schmidt-Cassegrain telescopes for 2'' operation. They allow use of 2'' accessories, such as the LUMICON 2'' EASY-GUIDER for photography. They also allow use of 2'' eyepieces and/or 2'' star diagonal for viewing.

| | |
|---|---|
| 2'' adapter for C-8, Meade 2080, etc.... | **$26.00** |
| 2'' adapter for Criterion 4000, 8000 ... | **$26.00** |
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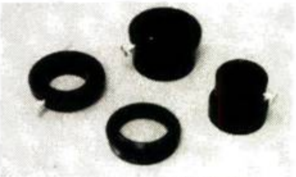

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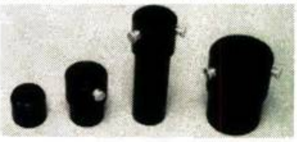

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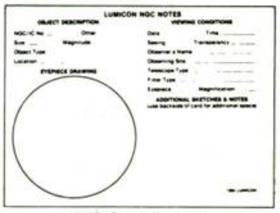

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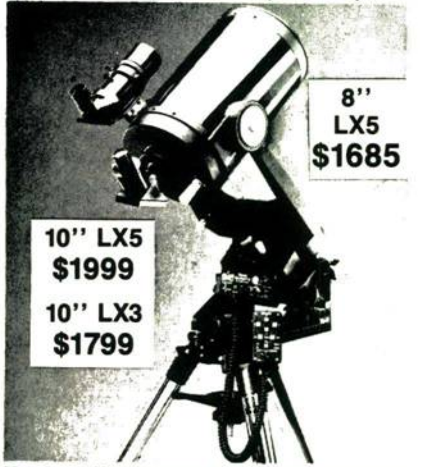

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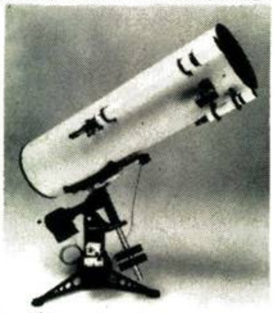

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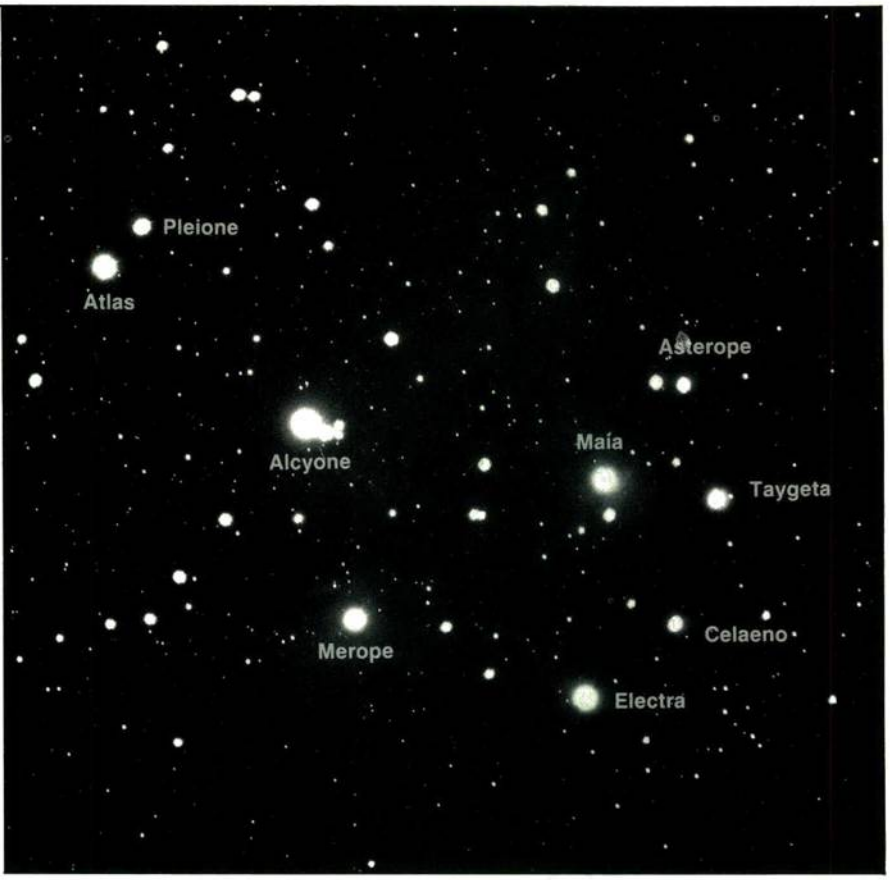
Eye on the Sky

# Mercury and Mars in the Dawn

by Robert Burnham



## The Wanderers

When daylight is almost gone, three planets can be seen: two in the southwest where twilight is strongest and one in the east. The two you see low in the southwest are **Venus** and **Saturn**. Venus is quite low — without a clear view right down to the horizon you may miss seeing it, despite its −3.9-magnitude brightness. At the same time each night Venus lies a little higher, but its climb toward greater visibility is gradual.

Saturn is substantially dimmer than Venus (0.5 magnitude) and begins the month with an altitude about ten times that of Venus. But while Venus climbs higher every night, Saturn is sinking toward the Sun. By month's end their relative positions are reversed: Saturn will be all but invisible and Venus will stand out clearly. On the 22nd, the crescent Moon slips past them, but you'll need to start looking soon after sunset if you want to catch sight of the "fingernail" Moon below the Venus-Saturn pair.

When the sky is fully dark, **Jupiter** shines clearly over the southeastern horizon. With a brightness of −2.8 magnitude Jupiter's white gleam is unmistakable — more so because no star in this region of the sky (Pisces) can challenge it.

After Venus and Saturn set, Jupiter will have the sky to itself until the predawn hours approach. The last two naked-eye planets, **Mercury** and **Mars**, are grouped together in the east-southeast as the morning sky begins to lighten. Both planets lie in Virgo near the 1st-magnitude star Spica. Mars is at magnitude 1.7, almost half as bright as Spica, and shines with a ruddy color. Mercury (−0.3 magnitude) is distinctly brighter than either Mars or Spica and has a warm tint.

During November Spica climbs steadily higher with Mars following at a slower pace. Mercury, on the other hand, pops into view during the first few days of November, pulls up from the horizon toward Mars, and reaches greatest altitude (10°, forty-five minutes before sunrise) around November 13. Then it sinks back and disappears into the twilight haze by month's end. Mercury's conjunction with the Sun is on December 23.

On November 18, the **Moon occults Spica** for viewers in Hawaii. At Honolulu the star vanishes behind the Moon's bright limb at 5:10 a.m. local time. At more westerly Hawaiian locations the occultation occurs progressively earlier; allow yourself an hour or so to get situated. You will need binoculars to observe the star as it disappears.

Peak activity for the annual **Leonid meteor shower** occurs this year in the late evening hours of November 17, and carries over into the wee hours of the 18th. The Moon, an old waning crescent, won't rise until roughly 3:30 a.m. At 2 a.m. the radiant in the head of Leo is well up in the east, and from a dark-sky site you should spot a Leonid every minute or so. The meteors are fast and bright, often leaving faintly glowing trains that dissipate after a few seconds.

At about thirty-three-year intervals the Leonids put on a great "storm," in which hundreds or thousands of meteors appear every minute. We aren't due for another storm for at least a decade — the last was in 1966 — but it's good to keep an eye on each year's Leonids. You'd hate to miss a blitz like that of 1966!

**Above: The Pleiades are a splendid cluster to study in binoculars. How many Pleiads can you see with binoculars versus the unaided eye? Photo by Paul Borchardt.**

**Opposite page: A bright meteor zips in front of Polaris, forming a fleeting celestial "reticle" in the sky. Chris Cook used a 24mm lens at f/4 on Ektachrome 200 and a 2-hour exposure.**

## The Starry Sky

Though the calendar says winter won't begin for weeks, the cold nights of November — and the stars they display — proclaim the coming season. In the early evening, autumn's stars are arrayed across the south, while winter's are rising behind them in the east.

Setting in the west are a few remnants of summer: three bright stars make a large triangle resting on its longest side. Vega (on the right) and Altair (left) form the base, while Deneb marks its upper tip. Vega belongs to **Lyra** the Lyre, Altair to **Aquila** the Eagle, and Deneb to **Cygnus** the Swan.

To the left of Aquila, **Capricornus** the Sea Goat and **Aquarius** the Water-Carrier

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

# November Night Sky

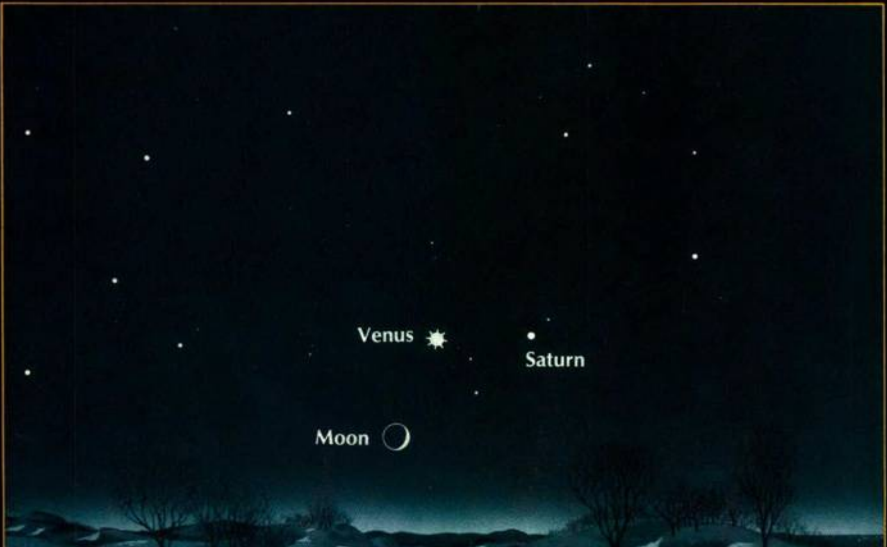
Full Moon
November 5
11:46 a.m. EST

Last Quarter
November 13
9:38 a.m. EST

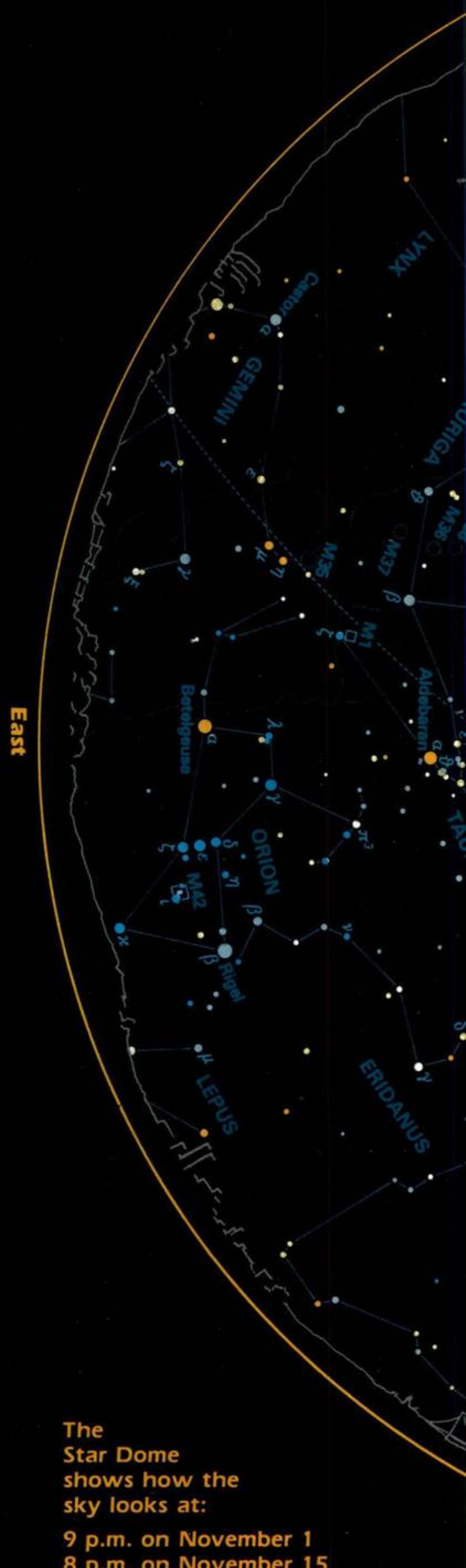
New Moon
November 21
1:33 a.m. EST

First Quarter
November 27
7:37 p.m. EST

| | |
|---|---|
| **2nd** | Pluto is in conjunction with the Sun. |
| **4th** | Jupiter lies 4° south of the nearly full Moon in the early morning hours. |
| **5th** | Full Moon occurs at 11:46 a.m. EST in Aries. |
| **10th** | Venus lies close to Antares in the evening twilight. |
| **12th** | Mars passes north of Spica in the morning twilight; Mercury lies to the southeast of Mars. The Moon is farthest from Earth at 12:54 p.m. EST: 251,283 miles (404,400 kilometers). |
| **13th** | Mercury is at greatest western elongation (and best visibility) in the predawn sky. Last Quarter Moon is at 9:38 a.m. EST in Leo. |
| **17th** | The Leonid meteors reach their peak activity late tonight and tomorrow morning. |
| **18th** | Spica is occulted for viewers in Hawaii, the eastern Pacific, and central South America (see text). |
| **20th** | Venus passes 2° south of Saturn. |
| **21st** | The Moon is New at 1:33 a.m. EST in Libra. |
| **22nd** | Venus, Saturn, and the crescent Moon form a close group in the evening twilight. |
| **24th** | Venus passes less than 1° south of Uranus. The Moon is closest to Earth at 9:49 a.m. EST: 227,925 miles (366,810 kilometers). |
| **27th** | First Quarter Moon occurs at 7:37 p.m. EST in Aquarius. |

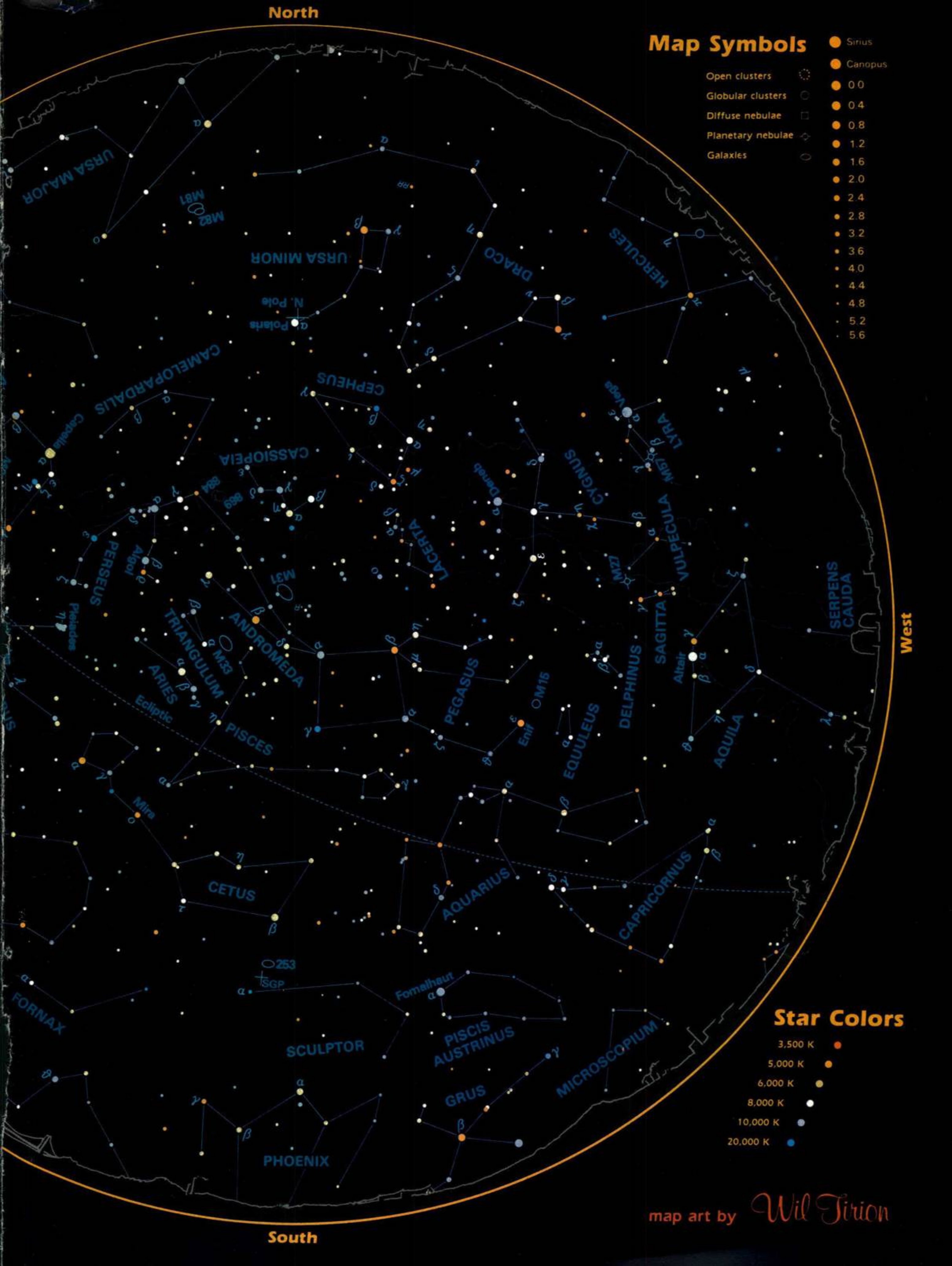


Looking southwest, November 22, half an hour after sunset



**The Star Dome shows how the sky looks at:**

**9 p.m. on November 1**
**8 p.m. on November 15**
**7 p.m. on November 30**


North
Map Symbols
Sirius
Canopus
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
URSA MAJOR
M81
M82
URSA MINOR
N. Pole
α Polaris
DRACO
HERCULES
CAMELOPARDALIS
CEPHEUS
CASSIOPEIA
Capella
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869
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Pleiades
M31
LACERTA
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SAGITTA
Altair
AQUILA
SERPENS CAUDA
West
DELPHINUS
EQUULEUS
Enif
M15
PEGASUS
ANDROMEDA
TRIANGULUM
M33
ARIES
Ecliptic
PISCES
Mira
CETUS
AQUARIUS
CAPRICORNUS
253
SGP
Fomalhaut
FORNAX
SCULPTOR
PISCIS AUSTRINUS
MICROSCOPIUM
GRUS
PHOENIX
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K
South

map art by Wil Tirion

**Top: An eerie aurora frames the Pleiades in this 20-second exposure by Lance Allred, who used a 50mm lens and Ektachrome 400 film.**

**Bottom: Don Trombino used ISO 64-speed film and an antique 5-inch f/10 refractor to record the occultation of Venus by the Moon on April 25.**

— members of the zodiac — follow the Eagle down to the horizon. Below Aquarius, the Southern Fish **Piscis Austrinus** swims eastward in vain, the bright bubble of Fomalhaut at its mouth. High above Aquarius, Flying Horse **Pegasus** gallops westward with his outstretched neck ending at Enif, his nose. Pegasus' body is the easily found Great Square.

Below the Square is a circlet of stars marking one of **Pisces**' two Fishes; the other is a zigzag configuration directly east of the Square. (Jupiter is also in Pisces temporarily, all but overwhelming its stars.) A cord linking the Fishes' tails meets at the star Alpha ($\alpha$), called Alrisha, "the Knot."

**Cetus** the Whale lies directly below Pisces, its wide body and smaller tail marked by a few 3rd- and 4th-magnitude stars. (The star Mira is variable in brightness and at present is rising toward maximum light, which will not occur until early February; it will not be visible as the map indicates.)

Underneath Cetus and Aquarius you may glimpse a few of the austral constellations. Below Fomalhaut lies **Grus** the Crane, and to its left the ghostly Firebird **Phoenix** looms dimly. The Sculptor's Workshop **Sculptor** is faint but contains a fine spiral galaxy for small telescopes in NGC-253. Farther east the fires in **Fornax** the Chemist's Furnace have burned out — why else is it so dark? Finally, the wandering path of **Eridanus** the River winds south over the horizon toward its unseen end at 1st-magnitude Achernar.

Let's return to Pegasus. While three stars in the Great Square belong to the Flying Horse, the star in the northeastern corner of the Square is Andromeda's. The Chained Princess is marked by a thin "V" of stars springing away from this corner of the Square. Andromeda is flanked by two galaxies: M-31, easy to see with the naked eye and a fine object in binoculars, and M-33 (in **Triangulum** the Triangle), which is more difficult to see but can be discerned as a hazy patch when the sky is extremely clear and dark.

If you look north between Andromeda and Polaris (the north star and tail-tip of the Lesser Bear **Ursa Minor**), you will find the wide "M" of **Cassiopeia** the Queen of Ethiopia. She was Andromeda's vain and boastful mother. To Cassiopeia's lower left is Andromeda's father King **Cepheus**. When Andromeda was threatened by the monster Cetus, she was rescued by **Perseus**, conveniently placed on the right of Cassiopeia. Perseus, along with Cassiopeia and part of Cepheus, lies in the Milky Way; a binocular sweep through here on a dark night reveals myriad tiny stars speckling the black sky.

In the northeast the Charioteer **Auriga** rolls up over the trees, its pentagonal shape following behind bright Capella. Poking Auriga with one horn is **Taurus** the Bull, home to two of the prettiest star clusters in the sky — the Hyades and Pleiades (see Skylore). Taurus' enemy is the Hunter **Orion**, which stands with one leg thrown up over the edge of the world.

After midnight the sky changes considerably. The western stars set with Pegasus close on their heels. Orion dominates the southeast and Taurus the south; behind Orion trots his hound **Canis Major**. Higher up follow **Cancer** and **Leo** — star-figures that extend eastward into the spring sky.

## Skylore

The Seven Sisters have long been familiar, but how many people today can name them? The daughters of Atlas and Pleione — Maia, Merope, Asterope, Taygeta, Celaeno, Alcyone, Electra — were famous in Greek mythology both for their beauty and their devotion to their father, who was compelled to uphold the world for taking the part of the Giants in the war against Zeus and the gods.

If you're like most people, a naked-eye look reveals only six stars, arrayed in the shape of a tiny dipper. (Binoculars of course add dozens.) The "lost Pleiad" has been an endless source of speculation and myth-spinning down the ages. One legend says that Merope, having married a mortal, was so ashamed she hid her face. Another claims Electra came down from the heavens to defend Troy (founded by her son Dardanus) from the Greeks. When the city was sacked, she was too grief-stricken to return to her stellar sisters.

In his book on Greek myth Robert Graves assumes that one Pleiad has actually faded since classical times, a highly improbable event. Astrophysics aside, Aratus, who wrote about 270 B.C., mentions the "sisterhood of seven" but goes on to say that only six are apparent to the eye. Many mythologies the world over also see seven significant objects — doves, maidens, dancers, etc. — one of which is missing. The plainest and most likely explanation is that the seventh Pleiad (or whatever) simply wandered into the gap between celestial reality and the mystical appeal of the number seven.

Starting about 4000 B.C. and running for roughly two thousand years, the Pleiades' heliacal rise (in late morning twilight just before the Sun rises) occurred at the vernal equinox and betokened the joyous return of life to the world. But as precession shifted the constellations through the seasons, the little asterism picked up darker meanings. The name Pleiades is usually taken to derive from the Greek word for sailing, and the group's rise at sunset was taken to mark the beginning of the bad weather season. Since it has become visible only in winter, the Pleiades are often associated with death, and November 15th, when the group crosses the meridian at midnight, is sacred to many peoples.

But not all Pleiades associations are gloomy. One wry legend comes from Arabia and concerns a rich man who sought a wife among several beautiful sisters. He pleaded his suit eloquently, yet he was rebuffed by each in turn. On the way home he concluded that by rejecting him they were really asking for proof of his wealth. He therefore gathered his most valuable possessions and returned, driving a great herd of camels before him.

You can see the outcome in Taurus this evening if the sky is clear. The sisters (the Pleiades) stand, patiently awaiting the return of the man (Aldebaran) and his camels (the Hyades). Will his wooing be successful this time? The legend neglects to answer, but something tells me it won't. For as fast as his camels walk west toward them, the sisters draw back just as swiftly!

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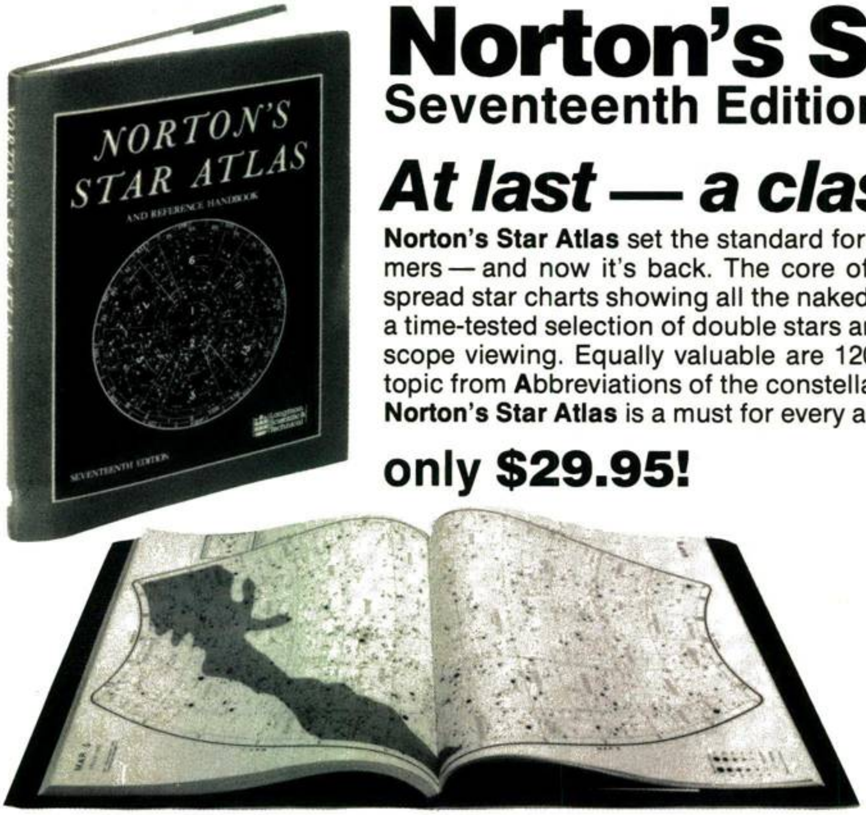

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Gazer's Gazette

# Jupiter's Best Show in Twelve Years

**by Jose Olivarez**

As you read this, Jupiter is putting on its best show in twelve years. During October and November the planet displays its biggest telescopic disk since 1976; the planet won't be this large and bright again for another twelve years. Even low magnifications will render an image of the planet nearly as large as a naked-eye view of the Full Moon. If you can get your hands on a telescope, do so. You might enjoy observing Jupiter's changeable cloud patterns so much that you end up studying the planet and perhaps even contribute your own scientific data.

The reason Jupiter is currently so large is that 1987 is the planet's perihelic year, a time in Jupiter's 11.86-year orbit when the planet makes its closest approach to the Sun. Jupiter reached perihelion on July 10, 1987, when its distance was 735 million kilometers from the Sun. Because Jupiter is still near perihelion, the planet continues to appear brighter and bigger in October and November than usual.

On October 18, 1987, Jupiter reached opposition. The configuration would be apparent if we could hover directly above the plane of the solar system: we would see the Sun, Earth, and Jupiter lying in a straight line with Earth in the middle. From our vantage point on Earth, Jupiter is now opposite the Sun in the sky, rising when the Sun sets, setting when the Sun rises. The months leading up to, during, and after opposition are ideal for observing a superior planet — one with an orbit greater than Earth's — because the planet's disk is fully illuminated by the Sun, visible all night, and as close to Earth as it is going to be for that apparition.

At opposition, Jupiter shines at a bold −2.9 magnitude and exhibits an enormous equatorial diameter of 49.73". This is nearly the largest dimension the planet can reach, and it will continue above the 49" size until November 5. The size of Jupiter's disk remains above 40" throughout the rest of 1987, providing the observer with a generous disk upon which to look for ever-changing cloud features. Telescopic magnifications of 40x will produce a disk that is slightly greater in apparent diameter than an unaided view of the Full Moon.

Besides the planet's large apparent diameter, there are two other reasons why observers should focus their attention on Jupiter. The first is to participate in an observing discipline begun one hundred years ago by an amateur astronomer. The patrol work, which is still conducted by a number of dedicated amateurs in the United States, Europe, and Japan, was begun by A. Stanley Williams in England during the Jupiter apparition of 1886-87, because "no attempt had hitherto been made to subject all the visible markings of Jupiter's surface to such a systematic examination, as to bring out the details of their relative motion, and the changes which they from time to time undergo." The detailed results of Williams' pioneering observations with a 6.5-inch Calver reflector were published in 1899 in a book entitled *Zenographical Fragments*. Indeed, the observing methods Williams used, such as recording the intensity of and changes in Jovian features and fixing the longitudes of those features by timing them as they cross the Central Meridian (the imaginary line bisecting the planet through the poles) are still in use today.

A second reason to observe Jupiter this year is that the planet is not as actively patrolled by professional astronomers as it was even a decade ago. Monitoring Jupiter's cloud patterns is firmly in the hands of enthusiastic observers who, by making careful, detailed observations, can contribute to the one hundred-year-old Jovian record that has been largely amassed by amateurs before them.

### An Active Planet

Larger than all the other planets and satellites combined, Jupiter is a colossus, rich in telescopic detail and changing features. As revealed by large telescopes and more vividly by *Pioneer* and *Voyager* spacecraft, Jupiter's atmosphere is marked by alternating bands and eddies of multicolored clouds and a dazzling array of storm systems. Jupiter is a gaseous world without a surface to speak of, though it may harbor a small rocky core twenty times more massive than Earth. The features we see float on a mantle of liquid molecular hydrogen, which in turn envelops a thick layer of metallic hydrogen (a high-pressure form of hydrogen) 25,000 to 30,000 kilometers below the cloud tops.

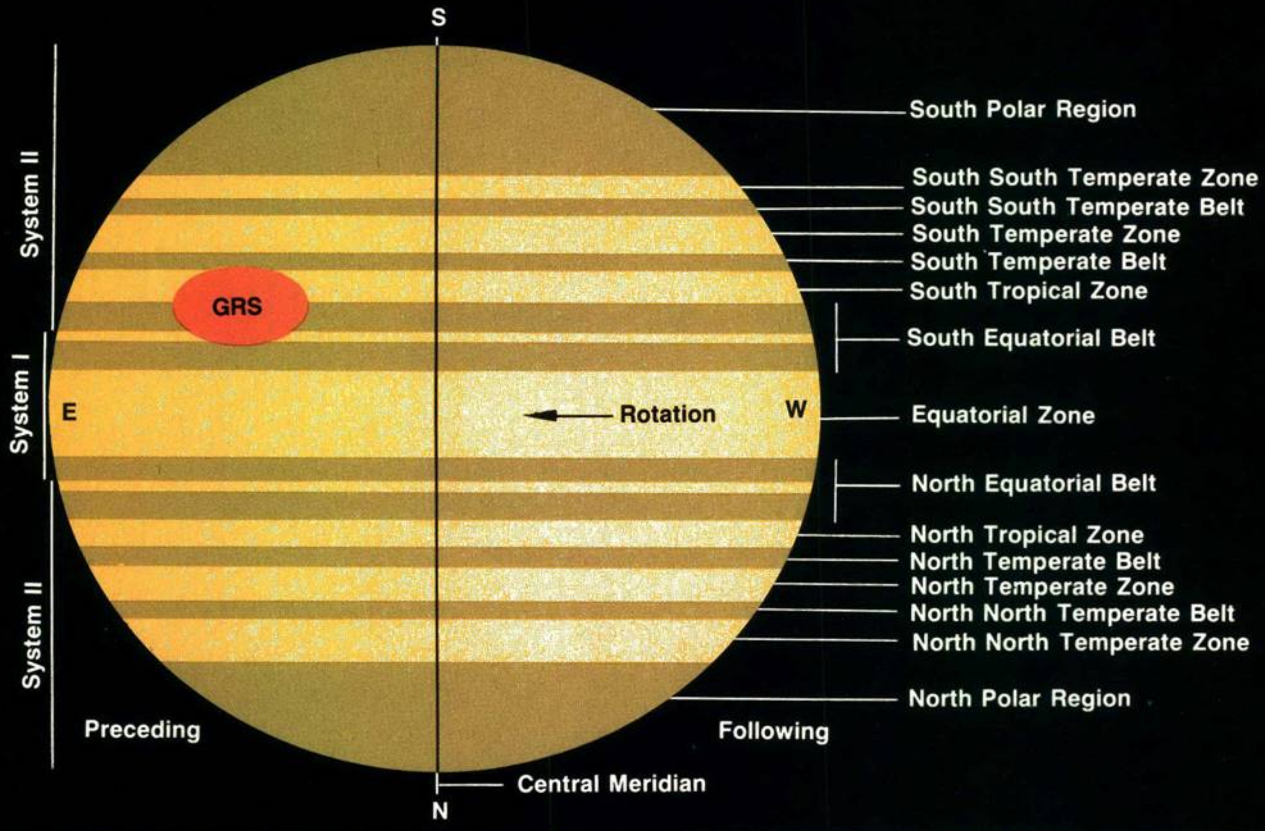
Jupiter's atmosphere is in constant motion, driven by the planet's 9.8-hour rotation period, by heat escaping from its warm interior, and by sunlight absorbed from above. The cloud tops are violently churned by hyper-hurricane force winds that typically exceed 300 kilometers per hour in the equatorial regions and have been measured as high as 520 kilometers per hour in the north temperate regions. These winds produce continuously changing cloud patterns that make for fascinating — and sometimes surprising — observing.

### Jovian Nomenclature

Stretched parallel to the planet's equator is a system of bright zones and dark belts representing regions of high pressure (the zones) and low pressure (the belts). The belts visible in most telescopes are more or less permanent features. These include the North Equatorial Belt (NEB), South Equatorial Belt (SEB), South Temperate Belt (STB), and North Temperate Belt (NTB). Bright zones separate the belts; the Equatorial Zone (EZ) is the most obvious because it separates the two most prominent belts on the planet.

To provide a convenient and yet accurate method of noting and classifying these belts and zones, the British Astronomical Association (BAA) standardized a nomenclature based primarily on latitude. In this scheme, belts and zones alternate from the equator to the poles in this order: equatorial zone, equatorial belt, tropical zone, temperate belt, temperate zone, and polar regions. Belts and zones are further specified by the hemisphere in which they appear. For example, the Great Red Spot is located in the South Tropical Zone (STrZ).

## Jupiter Nomenclature Chart


S
System II
System I
System II
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Rotation
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Preceding
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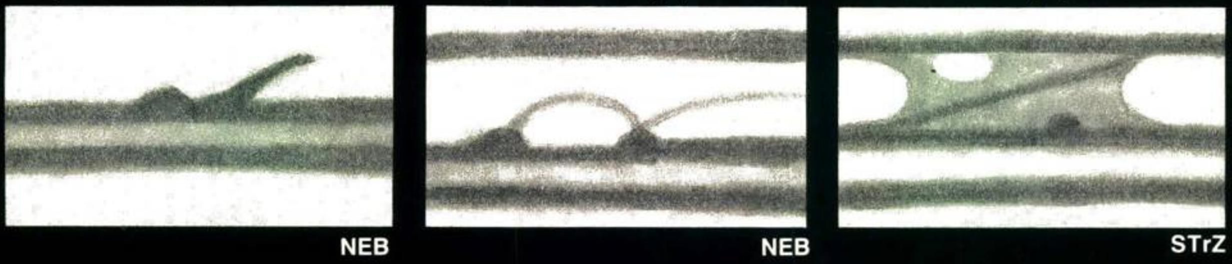
Central Meridian
N
South Polar Region
South South Temperate Zone
South South Temperate Belt
South Temperate Zone
South Temperate Belt
South Tropical Zone
South Equatorial Belt
Equatorial Zone
North Equatorial Belt
North Tropical Zone
North Temperate Belt
North Temperate Zone
North North Temperate Belt
North North Temperate Zone
North Polar Region

Latitudinal nomenclature chart for Jupiter established by the British Astronomical Association. Jupiter's cloud features rotate at the rate indicated by System I (9h50m30.003s) or System II (9h55m40.632s).

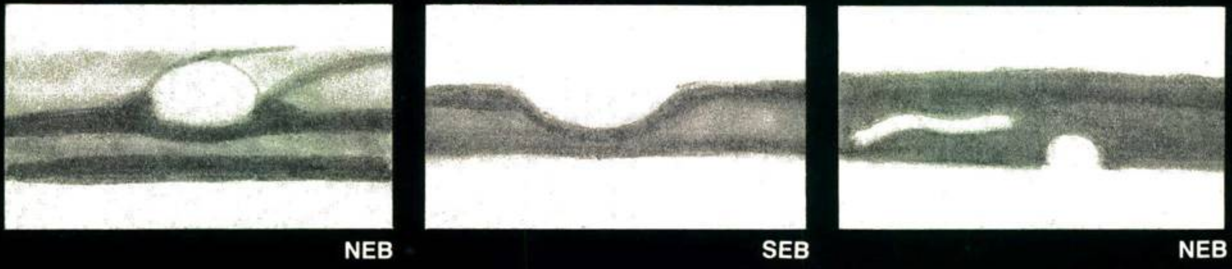
## Jupiter Cloud Markings

A sample of some of the prominent markings found in Jupiter's clouds, including their regions and whether the markings are dark (D) or white (W). Sketches by Jose Olivarez.

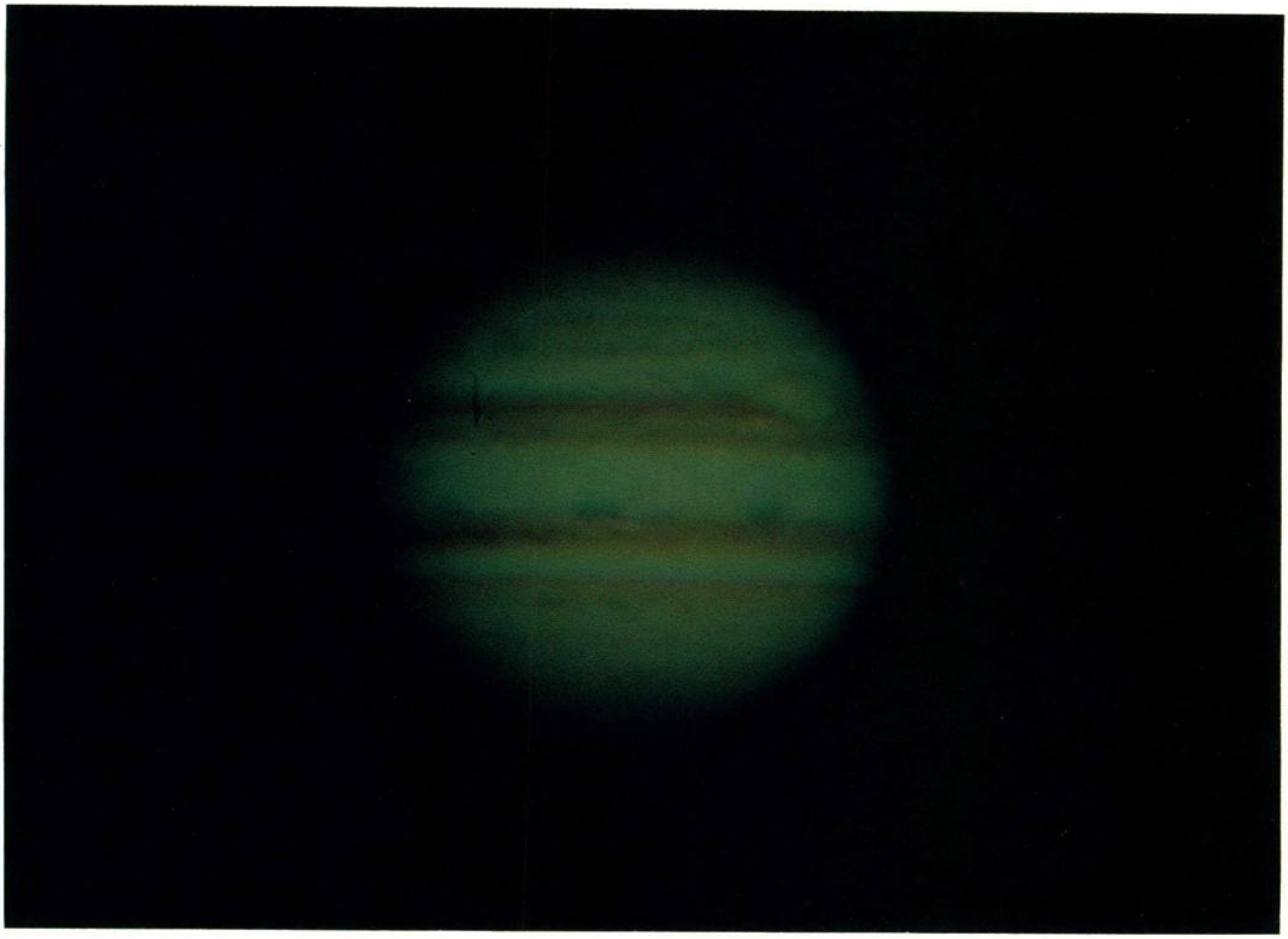


**Projection (D)** **Loop Festoon (D)** **Disturbance (D)**

NEB
NEB
STrZ



**Oval (W)** **Bay (W)** **Notch and Streak (W)**



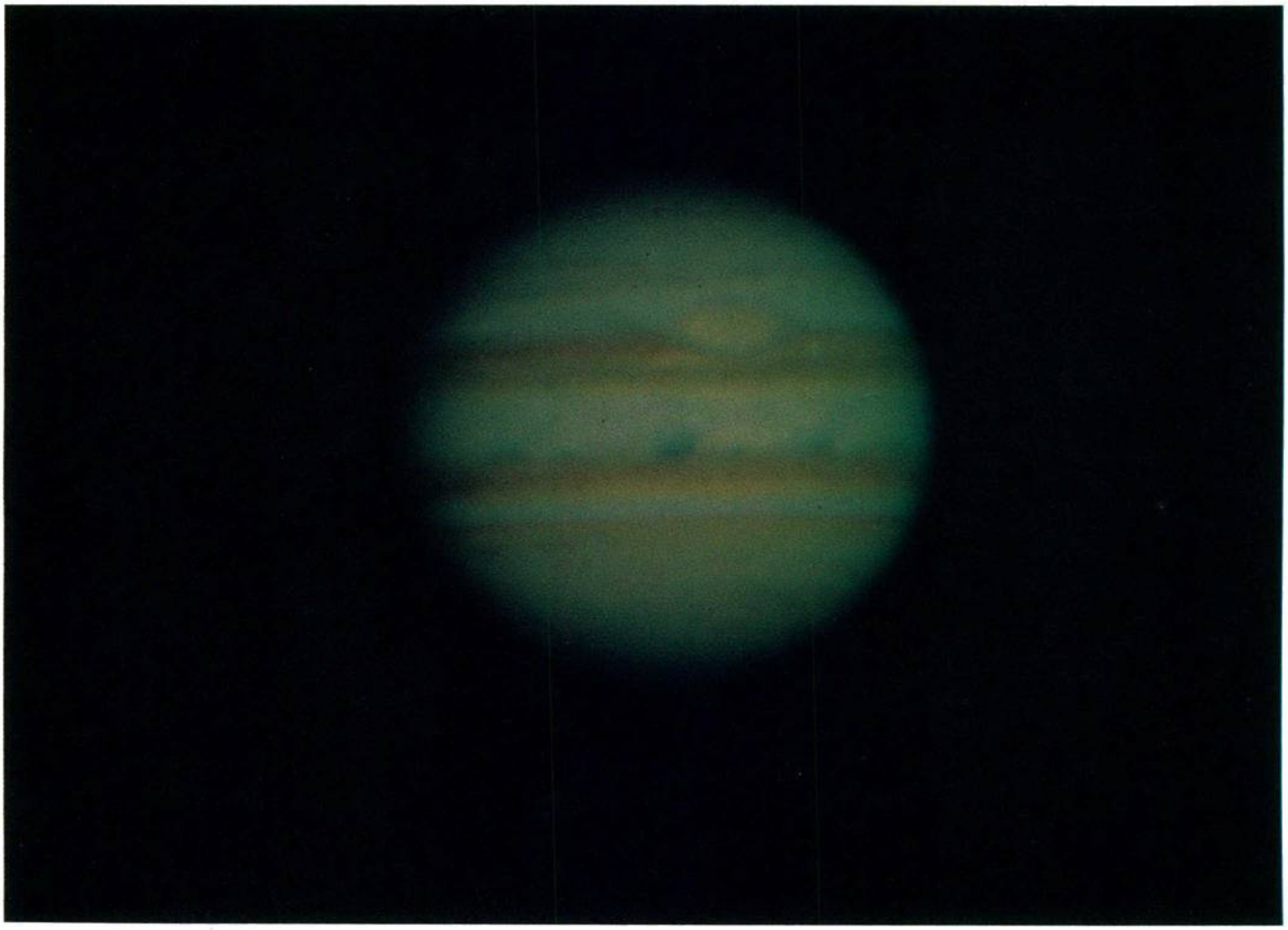
In addition to designating surface regions, the BAA also adopted two separate rotation periods for Jupiter, because the visible cloud patterns do not rotate synchronously across the planet. The two rates are called System I and System II. System I includes the rapidly rotating Equatorial Zone, the adjacent south edge of the North Equatorial Belt, and the north edge of the South Equatorial Belt. The rotation period of these regions is 9h50m30.003s. All other latitudes on the planet are assigned to System II and rotate in 9h55m40.632s. These two systems are applied when observing transits of Jovian features.

Because the belts and zones are more often than not churned up by short-lived dark and bright features, the smooth regularity of the primary features shown on Jovian nomenclature charts is not a complete representation of the planet as seen through the telescope. Various terms have been used to describe these intrusive little clouds, but there are specific types that commonly occur. A useful classification was developed by Phillip Budine and Elmer J. Reese of the Association of Lunar and Planetary Observers twenty-seven years ago. The Budine-Reese system categorizes these finer features as Dark Markings (D) or White Markings (W) and describes the specific types as follows:

- *Projection (D).* A dark protuberance on the edge of a belt. It may or may not be darker than the main body of the belt. Frequently seen on the southern edge of the NEB.
- *Bar or Rod (D).* A very elongated dark condensation with its major axis usually parallel to the equator. In some instances a rod may be an isolated short section of an otherwise invisible belt. Occasionally seen on the northern component of the NEB.
- *Festoon (D).* A dusky filament or thin dark wisp crossing a zone or looping out into a zone.
- *Loop Festoon (D).* A strongly curved dark festoon beginning at a projection on a belt edge, looping out into the adjacent zone, and returning to another projection on the same belt edge. Frequently seen in the NEB Zone — the narrow zone dividing the NEB.
- *Column (D).* A columnlike dusky area in a zone. A column may either be vertical or somewhat inclined. In recent years these have been seen primarily in the STrZ.
- *Disturbance (D).* A large dark or dusky area more or less sharply defined and usually mottled with smaller detail that may assume unusual shapes. True disturbances seem to be limited to the STrZ and the SEB Zone — the narrow zone dividing the SEB.
- *Oval (W).* A white, medium-to-large, round or oval-shaped area that is fairly bright and well defined. Very common in the EZ.
- *Nodule (W).* A small, very bright spot, usually round and not much larger than the disk of Ganymede, Jupiter's largest satellite. Occasionally seen in the SEB, NEB, and the polar regions.
- *Notch (W).* A small, semicircular white indentation in the edge of a belt, usually somewhat brighter than the adjacent zone. Notches are frequently found along the north edge of the NEB.
- *Bay (W).* A large, usually white semi-oval indentation in the edge of a belt. The most famous example is the Great Red Spot Bay (Red Spot Hollow) in the southern part of the SEB.
- *Rift (W).* A long, usually thin, bright streak extending more or less horizontally along the interior of a belt. May occur in the SEB or NEB when the belt is very dark and prominent.
- *Streak (W).* A very elongated white spot. When situated within a belt, a streak may be a fragment of a rift.

### Outstanding Jovian Features

All of Jupiter's large-scale structures and events occur primarily in its southern hemisphere. These include the Great Red Spot, the White Oval Spots of the South Temperate Belt, the Classical South Tropical Zone Disturbance, the South Equatorial Belt Disturbances, and a new phenomenon occurring in the South Equatorial Belt called Bright Streak Developments. These large-scale structures are



either long lived (Great Red Spot, White Oval Spots, STrZ Disturbance) or cyclical (SEB Disturbances and SEB Bright Streaks) and have been active for years or decades. In contrast, the northern hemisphere of Jupiter is relatively quiet and usually exhibits only the smaller bright and dark features that are common throughout the planet's atmosphere. This asymmetric activity between the northern and southern hemispheres is one of Jupiter's most overt characteristics and the reason astronomers pay more attention to the planet's southern latitudes.

### The Great Red Spot

The Great Red Spot (GRS) is without doubt the most outstanding large-scale feature on Jupiter. It was most likely first seen by Giovanni Cassini in 1665 and was definitely noted in 1831 by the German astronomer Heinrich Schwabe. The GRS is characterized as an anticyclone — a long-lived high pressure bulge in Jupiter's southern hemisphere. The reddish cloud tops are cool and complete one counterclockwise rotation every six days. The Red Spot's longevity is attributed to adjacent opposing wind forces that make its circulation appear analogous to a wheel spinning between two oppositely moving surfaces. The long-lived white spots are believed to survive as little vortices in the same way.

In late 1986 the GRS appeared as a well-defined pinkish ellipse 26,000 kilometers long and about 11,000 kilometers wide. The GRS has not been intense in appearance since it faded in 1976 after twelve consecutive strong apparitions. The last time the GRS attained great prominence was in 1960-61 when it appeared as a dark orange ellipse so intense it could be easily seen in small telescopes.

But even though the GRS has not been well defined lately, the Red Spot region can still be readily seen because of the visibility of the Red Spot Hollow that intrudes into the southern edge of the SEB. The Red Spot Hollow is the large oval area the GRS occupies. It is usually dull and hard to see when the Red Spot is prominent, but it becomes bright and white when the GRS fades. Throughout most of 1986 the Red Spot Hollow was visible as a large oval ring within which the GRS was seen darkening.

The movement of the Great Red Spot and its Hollow has generally been in the direction of increasing longitude, but the motion is erratic. The GRS can move forward or backward and drift ahead of or behind other features. This makes predicting the precise longitude of the Red Spot in the months ahead difficult.

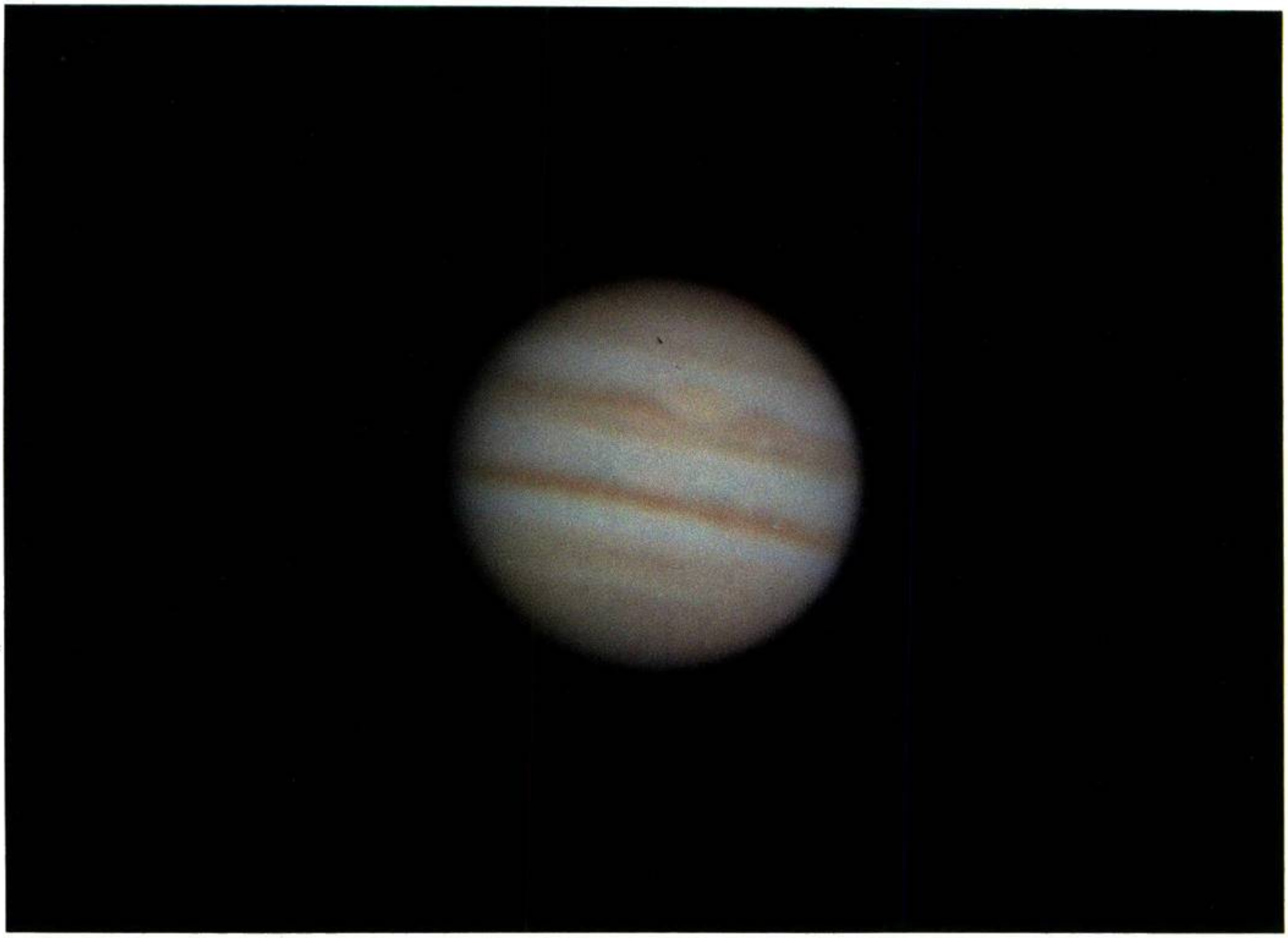
### Three White Oval Spots

After the Great Red Spot the second longest-lived features on Jupiter are the three White Oval Spots now situated in the South Temperate Belt. They were first seen in 1939 as rather inconspicuous and extended brightenings in the South Temperate Zone. As time went on, the bright sections shrank and became much brighter. By 1947 they had become well formed and took on the appearance of long shallow bays on the southern edge of the STB. For identification purposes these long bays were each assigned two letters: B-C, D-E, and F-A. The first letter represented the feature's preceding edge (leading in the direction of the planet's rotation), and the second letter represented the following (trailing) edge.

In the following forty years these bays shrank into bright ovals that today look more like white round spots in the STB. The spots are now referred to as BC, DE, and FA. (In 1984 the STB became broader and engulfed BC, DE, and FA, so they no longer appear to be features of the South Temperate Zone.)

From an analysis of how BC, DE, and FA shrank over the last four decades, Elmer J. Reese predicted several years ago that these spots could shrink from existence by 1985. However, their shrinking rate has decreased as they have gotten

**The photos on these pages show wispy festoons extending across the Equatorial Zone from blue "OL" features lying along the southern edge of the North Equatorial Belt. The photo on the opposite page was taken about one hour before the photo above. Photos by Jean Dragesco.**



**Recent observations of the Great Red Spot suggest this famous feature may be making something of a comeback after years of indistinctness. Donald Parker of ALPO took this photo August 16, 1987, with a 12.5-inch f/6.5 reflector and Ektachrome 200 film. Exposures were about 4.5 seconds at f/123.**

smaller, and they continue to exist. DE is now the brightest of the three and is about 8° of longitude long. (One degree of Jovian longitude equals 1,187 kilometers.) BC is also about 8° long and second in order of brightness. FA is the smallest of the three and harder to see, yet FA merits watching because after forty-eight years of existence it may disappear before this decade ends!

Today these long-lived white oval spots are characterized as 9,000-kilometer-wide vortices in Jupiter's upper atmosphere.

### South Tropical Disturbance

The third longest-lived feature observed on Jupiter is the South Tropical Zone Disturbance. According to BAA Jupiter Reports, the disturbance began in 1901 as a small dark spot in the northern part of the STrZ, but it soon developed across the zone and became greatly extended in longitude. In its final years, just prior to fading away in 1939, it extended over 200° of longitude — halfway around the planet! Its development was complex, but it had one identifiable characteristic: its preceding and following ends appeared concave.

During the lifetime of this great disturbance the South Tropical Zone Disturbance interacted with the Great Red Spot on several occasions. The details of their meeting make some of the most interesting reading in Jovian observing history. An excellent account of the interactions is given in *The Planet Jupiter* by B. M. Peek and Patrick Moore.

After thirty-nine years of invisibility the STrZ Disturbance returned to prominence in 1978 for a major revival that really put on a show in 1979-80, according to Phillip Budine of ALPO. The revival began in December 1978, and by June 1979 it extended one-third of the way around the planet! A year later it spanned nearly 200°.

The disturbance continued to be active throughout 1983 but was seen only as fragmentary remnants of its earlier glory. It renewed itself again in July 1984, when I observed it as 35° long and well developed. The feature then lay adjacent to the Great Red Spot and exhibited the concave edges that were its identifying mark when it was observed forty-five years before.

Remnants of this disturbance continued to be observed through 1986 and may well be seen again during the current apparation of Jupiter. Watch for the disturbance somewhere along the bright STrZ. It may well again appear near the Great Red Spot and interact with this famous feature's whirling winds.

### A New Feature

Like the South Tropical Zone, the South Equatorial Belt has also been prone to long-term and cyclical disturbances. The most famous event to occur in this belt is the South Equatorial Belt Disturbance. No less than sixteen events of this type have been observed, the first in 1919. During these events the SEB was darkened by a chaotic outburst of matter that suddenly issued from the center of the belt and spread east and west from a stationary source. The last event was recorded in 1978 and has not recurred since. The reason for its vanishing act may be that the SEB has remained well established and dark over the last nine years.

As if to make up for this missing disturbance, a new type of SEB Disturbance appeared for the first time in July 1985. This is the SEB Bright Streak Disturbance that has now been observed on three different occasions over the last two years. The first of these disturbances was discovered by the Japanese observer I. Miyazaki on July 12, 1985, and was subsequently observed by the members of ALPO. The beginning of the activity, which consisted of a bright oval spot in the South Equatorial Belt Zone, was photographed by Donald Parker of Coral Gables, Florida, on July 14, 1985. Then in an eight-day period, the activity rapidly enlarged from a span in longitude of 11° (13,000 kilometers) on July 16, to 33°

(39,300 kilometers) on July 23. The disturbance consisted chiefly of bright spots, bright rifts, and festoons. The activity developed along the SEB Zone in the direction of decreasing longitude until it faded away over thirty days later.

The second event, which began on November 3, 1985, was also discovered by I. Miyazaki and underwent a similar development, beginning with a bright spot that rapidly developed into an inclined bright streak. This disturbance was also short lived, but it was followed by a third occurrence on December 13, 1986. The event displayed the same pattern of development as the previous events and was observed through the middle of January 1987.

Another development of this unusual repeating SEB Bright Steak Disturbance may well occur in the coming weeks or months. Observers should be on the lookout for a bright spot that suddenly appears in the SEB Zone, and then watch it as often as possible for rapid developments.

### Rapidly Moving Spots

Although Jupiter's northern hemisphere is usually quiet in comparison with the southern regions, this apparition may be an exception to the rule. It is very likely that an outbreak of rapidly moving spots on the southern edge of the North Temperate Belt at latitude +24° will occur. Indeed, there is observational evidence that the outbreak of rapidly moving spots in this latitude is periodic and happens at twelve-year intervals when the NTB lies nearest the planet's equator. Moreover, the cycle of activity has also been noted to coincide with Jupiter's perihelion.

One of the best observed cycles of the rapidly moving spots was that of 1964-65, when Elmer J. Reese and Bradford Smith of the New Mexico State University Observatory observed an NTB dark spot that made seven complete circuits of the planet in 268 days! The mean daily drift of the spot was −9.4° of longitude and corresponded to a mean rotation period of 9h48m18s by System II, which produced one of the shortest rotation periods ever recorded on Jupiter. The spot was calculated to be moving at 520 kilometers per hour relative to nearby cloud features.

The rapidly moving NTB spots were seen again in September 1975 by the Jupiter section observers of the Unione Astrofile Italiani. They observed a rapidly moving white spot near latitude +23° (the south edge of the NTB). This observation leads planetary observers to expect that the remarkable rapidly moving spots will be seen again during this apparition.

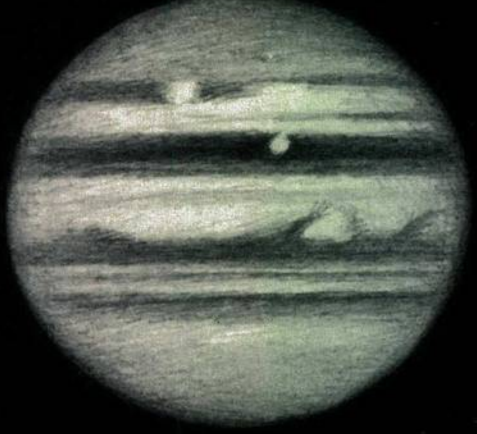
Observers should examine the south edge of the NTB for dark or white spots every time they train their telescopes on Jupiter. A Wratten 82A filter may aid in detecting the spots.

### Jupiter's Deep Holes

Another remarkable phenomenon of Jupiter's "quiet" northern hemisphere is

### Development of a Jovian Disturbance

November 3, 1985



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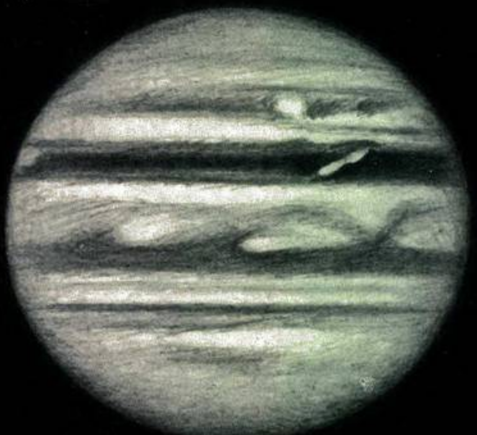
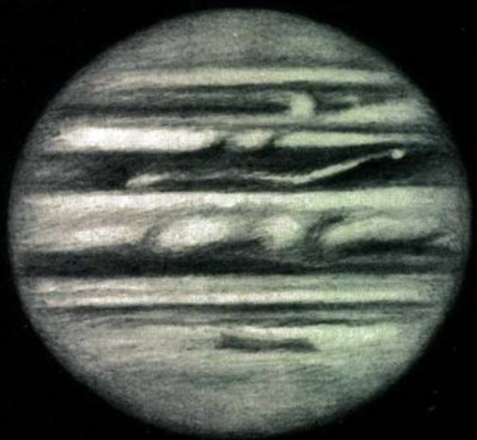


November 22, 1985



**These sketches, made over a period of nineteen days, show the development of the second South Equatorial Belt Disturbance in 1985. The disturbance appears as a white spot in the SEB in the top sketch; four days later it develops into a bright streak. Fifteen days later the disturbance stretches more than halfway across the disk. Sketches by I. Miyazaki.**

the blue spots and festoons lying along the southern edge of the NEB. In fact, all of the dark protuberances seen on the southern edge of the NEB at latitude 7° north are blue and a part of a discreet system of deep holes in Jupiter's cloud deck.

In 1983 I discovered twelve of these blue features distributed along the south edge of the NEB. These features and new ones that develop have been followed through the last four apparitions. Though the other features have changed or vanished during the past four years, one blue feature, designated OL-5 in 1983, still exists. I last observed OL-5 in late October 1986 and expect to see it during this apparition.

The darkness of these features is quite noticeable, though beginning observers may not be able to visually detect the bluish tint. A Wratten 25 red filter will make these features stand out. Through a red filter all blue features are darkened, and the bluish tints appear as the darkest features on the planet.

The blue features that appear only along the northern half of the Equatorial Zone exhibit characteristics that tie them together as one discrete phenomenon. They all have rotation periods that are very close to System I's rate, and they remain nearly stationary at the longitudes they occupy. The blue features appear with their bases adjacent to the NEB and look like spots or masses that in time develop graceful blue festoons that project or loop into the Equatorial Zone. There are usually twelve to fourteen blue features distributed around the planet at latitude +7° at any one time, and they are long lived.

In addition, infrared data taken by astronomers at the University of Arizona show that these blue features are discrete thermal sources much warmer than their surroundings. This suggests that they are probably deeper, cloud-free areas in Jupiter's atmosphere. Indeed, the blue features may be the deepest holes visible in Jupiter's cloud deck and may extend to a depth of about 100 kilometers below the top of the planet's troposphere. The bottoms of the holes may be about 100° C warmer than the higher level clouds and look blue because they are filled with droplets and snowflakes of frozen water.

Are Jupiter's equatorial blue holes water sources? Is it possible that the Equatorial Band (a narrow belt sometimes observed dividing the EZ) becomes a "water belt" when it is made up of material that springs from these deep blue sources as festoons? Look at Jupiter's equatorial blue features through your telescope and ponder these possibilities. Jupiter's dynamic atmosphere is full of intriguing surprises!

### An Amateur's Planet

There are few astronomical objects that offer the observer equipped with a modest telescope the variety of features and events Jupiter does. Although one might think such variations would occupy professional astronomers' time, the job of patrolling Jupiter's cloud patterns is almost entirely in the hands of lay observers. Professional interest in the planet, so evident prior to the *Voyager* flybys, has dwindled considerably, and future Jupiter missions are in doubt. Moreover, telescope time at observatories is too valuable to devote to monitoring any of the planets for unpredictable events.

Therefore, the planet with the largest changeable surface available for viewing in telescopes is open to systematic examination and discovery by any observer with a telescope, patience, a keen eye, and lots of enthusiasm. What better way to contribute to planetary astronomy and to perpetuate the Jovian patrol work begun a century ago by A. Stanley Williams?

Anyone seriously interested in observing Jupiter can obtain copies of the ALPO Jupiter Recording Forms, as well as information on how to time Jovian features, keep a record of observations, and sketch the planet by writing to the address below. Please include a legal-sized, self-addressed stamped envelope.

Jose Olivarez
ALPO Jupiter Recorder
1469 Valleyview Court
Wichita, KS 67212

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*Jose Olivarez is director of the Omnisphere and Science Center in Wichita, Kansas. He has been observing Jupiter since 1960 and is a Jupiter Recorder for the Association of Lunar and Planetary Observers.*

## Observing Jupiter: Practice, Concentrate, Persevere

A good 1.5-inch objective with a magnification of 30x readily shows Jupiter's two dark equatorial belts. A 2.4-inch objective at 100x shows three or four belts and, if it is prominent, the Great Red Spot — a large storm system that has been visible for over three hundred years. But discerning the more challenging cloud markings and events requires at least a 6-inch objective or larger. A 6-inch refractor (f/15) or a well-collimated 8-inch reflector (f/7 to f/8) with a fine-figured mirror is recommended as a minimum. Very high powers, however, are not necessary. A range of 150x to 250x used with 6-, 8-, or 10-inch apertures will suffice. I have seen the best Jupiter images and have made the most useful observations with 200x on 10- and 12.5-inch f/7 reflectors.

One of the more important things you can do to increase the planetary detail you can see is to practice observing. This can't be stressed enough. To the beginner, Jupiter may look like a bland disk crossed by two dusky belts. However, as you observe, you may get the "feeling" that there are more features to be seen on the disk. And so there are. But because Jupiter does not reveal its subtler cloud features easily, you must work hard to see them.

You can begin sharpening your observing faculties by concentrating on the disk and waiting for moments when the air steadies and the image sharpens. Look for contrasty details and shadings on the disk, always working to discern smaller dark or white features. Challenge yourself! When you think you couldn't possibly see any more detail, look again. Depending on your observing experience, the finer planetary features will become apparent to you after several days of systematic observing. If you are a beginner, it may take several weeks.

You might be able to speed up your skill in seeing Jupiter's markings by using color filters. The Wratten green 58 filter is effective for observing the low-contrast hues of blue and red that exist in the Jovian atmosphere. It cuts out both the red and the blue colors, thus enhancing the contrast of red and blue details that tend to permeate the planet's clouds. In addition, a light blue filter like the Wratten 82A is useful because it emphasizes the overall contrast between the belts and the zones.

Once you begin observing Jovian features, you can furnish scientific data for a number of studies of Jupiter. For example, timing a Jovian feature as it crosses the planet's Central Meridian can help determine the longitude of that feature, the feature's size, and its rotational rate. This procedure is not particularly complicated, but it requires access to tabular information in a current copy of the *Astronomical Almanac*, published by the U.S. Naval Observatory. Tables provided by the almanac allow you to convert transit times to a longitude value. (Instructions for making timing transits can be obtained by writing the Association of Lunar and Planetary Observers. The address is provided below.

Another important study involves observing the size, color, and rotational drift of the Great Red Spot. This information is needed to determine how this storm sustains itself and interacts with surrounding features. Other activities include estimating the changes in the size, color, and brightness of features and patrolling the planet for sudden outbursts of light or dark features that rapidly change.

— *Jose Olivarez*

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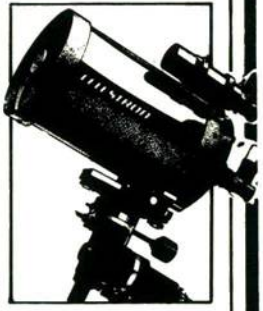

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Equipment Atlas

# Build a Heated Dew Cap for Less than $10

### by Harry Hammond

I enjoyed using my Schmidt-Cassegrain telescope when I first bought it. But that was before I experienced the discouraging effect of dew on the telescope's corrector plate, something other SCT owners undoubtedly worry about from time to time. On all but the driest nights in all but the driest climates, condensation on your SCT's corrector lens can be one of the most frustrating observing problems. Aside from ending your observing session prematurely, what can you do to beat nature at its own game?

Use a dew cap. But commercial dew caps cost more than I wanted to pay, so I decided to build a dew cap. At first I hung a paper bag over the end of my telescope's tube, but the paper didn't last long. Besides, using a paper bag on a $2,000 scope was like installing polyester seat covers in a Porsche. I wanted something more durable, more permanent, and more attractive.

## The Low-Tech Solution

I began scouting around the house for parts to build a better dew cap with. It should be easy, I thought. How difficult could building a simple cylinder be? I dug up some matte board, commonly sold at art and photo supply stores and used to make simple frames for photos and artwork. This material can be rolled into a large-diameter tube fairly easily, holds its shape indefinitely when properly fastened, and can be painted black. With this matte board I made a dew cap that would serve me forever, as long as I didn't accidentally sit on it or trip over it in the dark. On humid nights my telescope's corrector plate remained dew-free for at least forty minutes, and when a small amount of dew did appear, a blast from a hair dryer took care of it.

This happy situation continued for some time and would have continued indefinitely had I not discovered astrophotography. I wanted to make exposures longer than 40 minutes, so I began to think about building a more effective dew cap. How could I extend the period of time the telescope was free of condensation? The best solution was to heat the air surrounding the corrector plate just enough to stop the condensation of dew but not enough to affect the image. To accomplish this, I made a matte board dew cap with seven 2-ohm resistors held on by duct tape and powered by a 12-volt battery. The system works surprisingly well, and building this dew cap is a simple and fun project.

## Getting Started

To find the width of matte board you'll need to cut, measure the circumference of your corrector plate cell with flexible tape or a tape measure. Add one inch or so to this measurement for overlap so the matte board can be fastened to itself once it's rolled around the cell.

The width is easy enough to figure out, but how long should the dew cap be? As far as protecting the plate from moisture, the longer the better. But at some point you'll get diminishing returns, because the added length causes vignetting problems. Conventional wisdom holds that refractor dew caps should be about three times the length of the lens aperture. I used this figure as a guideline for constructing my dew cap. This made the dew cap 24 inches long.

However, I found that this caused vignetting during photography, so I cut the length back to 1.5 times the aperture. For my 8-inch SCT the unrolled dew cap measures approximately 12 inches by 30 inches.

After cutting the piece of matte board, you're ready to roll the matte board into a cylinder. An extra pair of hands is helpful here, so enlist a friend to do the fastening while you do the rolling. Place the matte board so that about one inch of the long edge covers the outside of the corrector cell. Gently wrap the board around the edge of the telescope tube. Work to

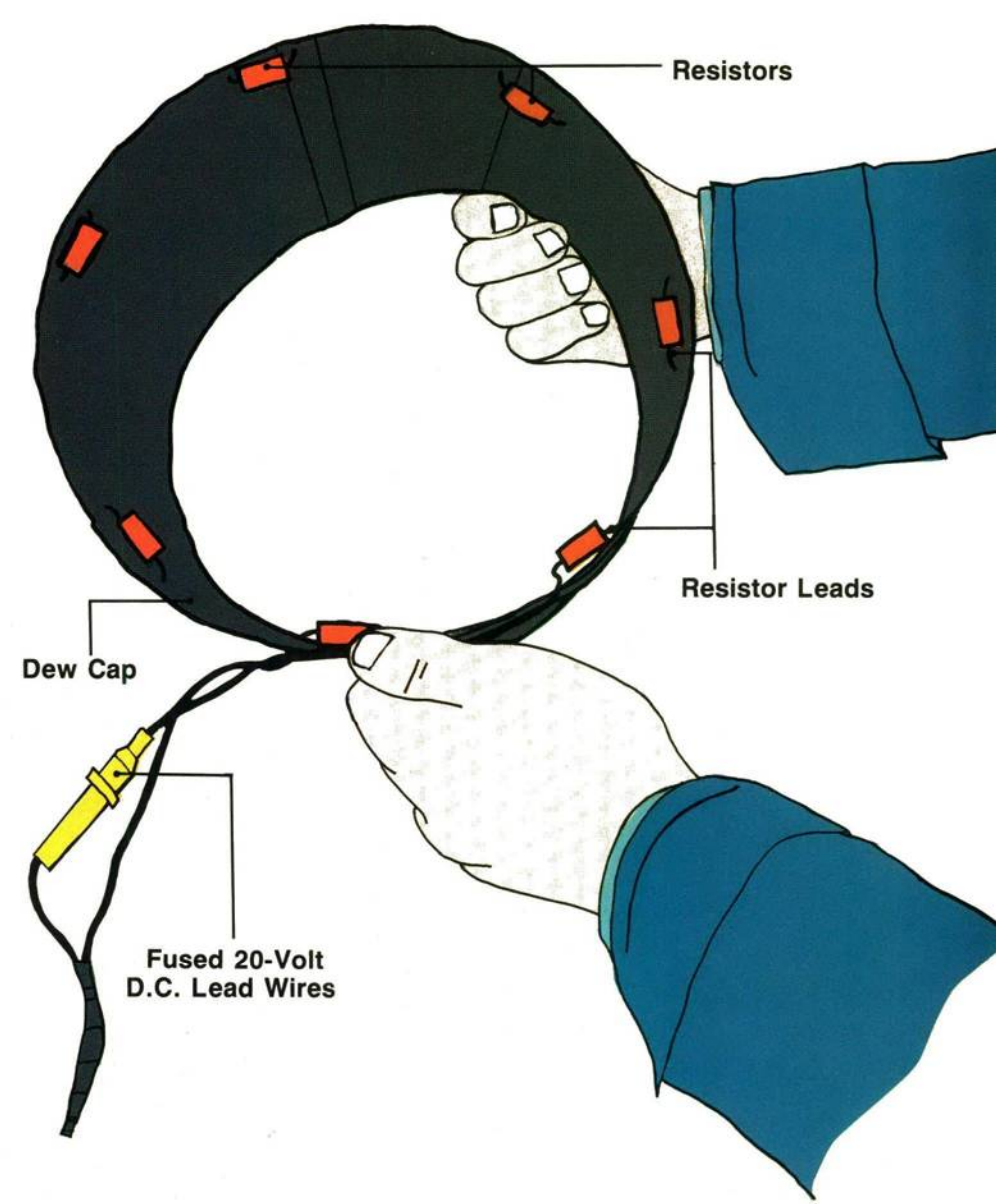
## Much Ado about Dewing

You've set up your Schmidt-Cassegrain telescope and are looking forward to a pleasant evening of observing. The sky is clear, and as the Sun goes down, the air starts to cool. For an hour or so you enjoy viewing your favorite Messier objects. Then suddenly you notice the cluster you're staring at seems dimmer and fuzzier than it was a few minutes before. What happened?

When you take a good look at your finder scope's objective and your corrector plate, you see that tiny droplets of water have formed on them. It isn't particularly cold or damp, and there are no clouds in the sky. What caused the dew to form?

Two related factors control dewing. The first factor is the relative humidity: the ratio of water vapor in the air compared with the maximum amount of water vapor the air can contain at the existing temperature. The amount of water vapor the air can hold is determined by temperature; the warmer the air, the more water vapor it can hold. The second factor, the dew point, is the temperature at which moisture in the air begins to condense into droplets, rather than staying suspended in the air. The dew point temperature varies with the quantity of water vapor in the air. Therefore, relative humidity is 100 percent when the air temperature equals the dew point temperature.

Relative humidity can be measured by an instrument called a hygrometer or by measuring the difference between temperature readings on dry-bulb and wet-bulb thermometers. Because of evaporation, the wet-bulb thermometer gives a lower reading than the dry-bulb thermometer. You can find the relative humidity by finding the temperature difference between wet and dry bulbs and checking



**The $10 dew cap, wired and ready for operation. The resistor leads are pushed through the cap wall and then twisted together and laid flat. A layer of electrician's tape placed around the tube insulates the circuit.**

keep the board tight against the cell, squeezing out any slack. The matte board should easily bend into a smooth, crease-free curve.

Once you wrap the board around to the starting point, lap the extra inch of board you allowed tightly against the other end and fasten it with a piece of duct tape. (Masking tape won't do; duct tape is stronger and stickier.) Now you're ready to close the circle at the other end of the cylinder. Bring the unclosed end to as perfect a fit as you can, and have your friend fasten the two layers of matte board with a single staple at the edge of the cylinder.

Next, cut a strip of duct tape as long as the dew cap and place the strip over the seam, firmly pressing with one hand while backing it up on the inside of the cylinder with the other. Remove the dew cap from the telescope and tape the inside seam the same way you taped the outside seam.

a meteorological table in a source like the *Handbook of Chemistry and Physics*.

If a sufficient amount of water vapor is in the air (indicated by a high relative humidity), water condenses on objects at or colder than the dew point temperature. However, you may notice that water collects first on the top surfaces of objects, that is, on areas exposed to the sky. Why is this so?

On a typical clear evening the air begins to cool slowly after the Sun sets. Objects like the ground and various metals are good conductors of heat and cool rapidly. Water is a poor conductor and retains heat for hours. Good conductors like metals radiate their heat quickly, while the surrounding air gives up its heat slowly, mostly by convection and conduction. When exposed to the sky, a telescope tube or lens loses heat constantly and chills the air nearby. If the temperature of the tube or optics falls below the dew point, water in the air condenses on the telescope.

Dewing is most likely to occur when the sky is clear and the air temperature is near the dew point. Checking a night's weather report may indicate a small range between air temperature and dew point; combined with a relative humidity of greater than 30 percent, this indicates a strong possibility of dewing problems after sundown.

If you have a Newtonian reflector, you may wonder why on damp nights your finder scope is fogged over and water runs off the telescope's tube, but the primary mirror remains dry. This is because the mirror is shielded by the long tube: the mirror never cools below the air temperature because it can't radiate much of its heat into the atmosphere. Similarly, an extension tube coupled to the front part of a Schmidt-Cassegrain, Maksutov, or refractor helps shield the lens or corrector plate from the air, limiting damp air circulation and reducing dewing.

Dewing is often severe enough that an ordinary extension tube is not effective for any length of time. Wet optics should never be wiped dry, because scratching optical surfaces with tiny particles of dirt or a rough cloth is easy. Covering the lens or corrector plate with dry, absorbent material like paper towels covered by the telescope's lens cap will dry up the water, as will a few seconds of hot air provided by a portable hair dryer. But the dew often quickly returns.

A better method is placing an electric heating system inside a dew cap, heating the air surrounding the lens or corrector plate slightly, and preventing the formation of dew. Raising the air temperature effectively lowers the relative humidity, solving the problem so that you can enjoy observing unhampered by nature.

— *Gene A. Lucas*

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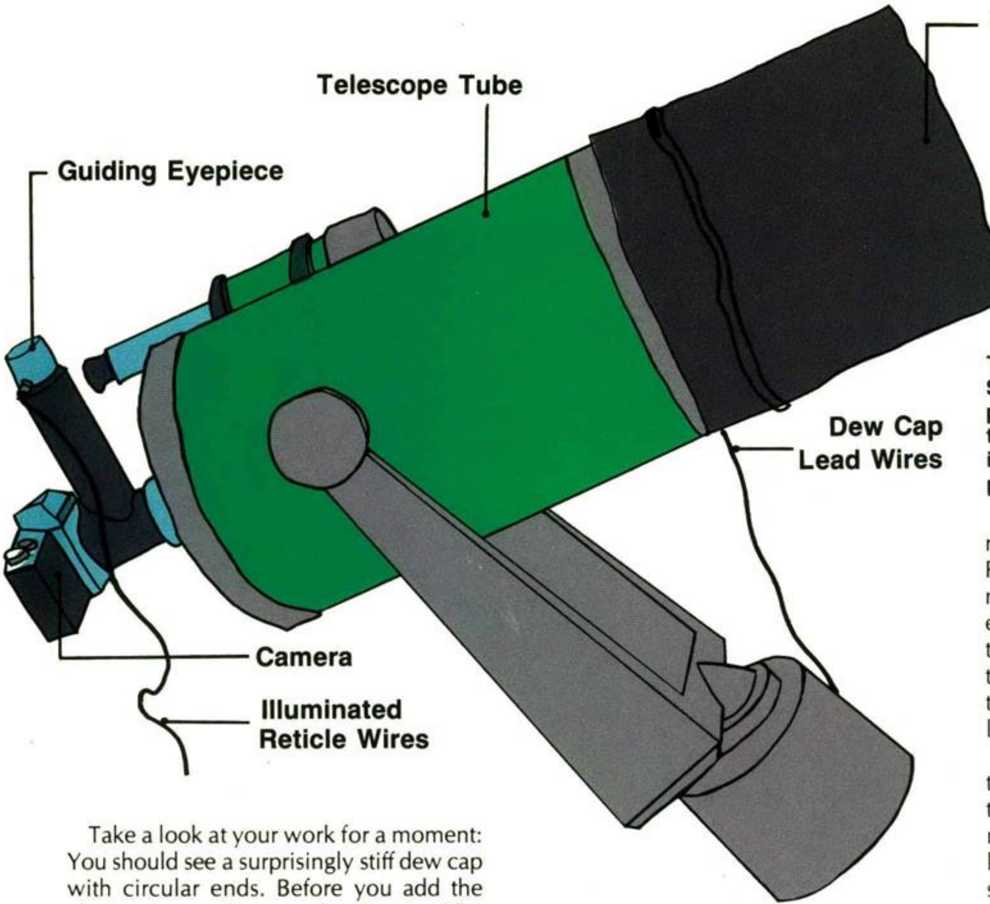

**The finished dew cap mounted on a Schmidt-Cassegrain telescope. After plugging in the curcuit and making sure the unit is producing heat, the observer is ready for a night of observing unhampered by moisture in the air.**

Take a look at your work for a moment: You should see a surprisingly stiff dew cap with circular ends. Before you add the electronics, apply a couple of coats of flat black spray paint inside and outside the cap, which will minimize stray light inside the cylinder and render the tape nearly invisible.

### Heating It Up

Very little heat is required to keep a surface dew-free. If the surface is heated to just one degree above the outside air temperature, water will not condense on it. An electrical circuit consumes power and gives off heat. A simple circuit that dissipates 8 to 12 watts (depending on the dew cap's size and on the relative humidity) will produce more than enough heat to keep your telescope's optical surfaces free of dew. This circuit uses off-the-shelf power resistors spaced uniformly around the inside of the dew cap, and a 12-volt car battery provides the power. The drain on the car battery is insignificant over a several-hour period.

What type of resistors should you use? To determine this, let's do a little number crunching. The equation used to determine the power consumed in a simple circuit is

$$P = V^2 / R,$$

where $P$ is the power in watts, $V$ is the voltage across the current, and $R$ is the resistance in ohms. The power consumed by the resistors is given off as heat, which is the stuff we're looking for. I found that a circuit giving off 10 watts yields more than enough heat to keep my corrector plate dry, even on rather damp nights. Using 10 watts as a starting point for our dew cap and a standard 12-volt car battery as the power source, we can turn the above equation around to discover how much resistance is needed. By doing so, we get

$$R = V^2 / P.$$

Plugging in values of 12 volts and 10 watts gives a resistance of (12 x 12) / 10 = 14.4 ohms. I got a supply of 2-ohm power resistors at a local electronic supply store and I used seven resistors (total resistance = 14 ohms) in my dew cap to construct the circuit, which consumes 10.3 watts of power. Unfortunately Radio Shack does not normally stock 2-ohm power resistors but offers 0.47-ohm and 10-ohm resistors instead. Thirty 0.47-ohm resistors will do the job just as well as seven 2-ohm resistors. No matter how many you use, string the resistors in a series circuit, connecting one to the next, until you use them all. Two ends of the resistor string then connect to the power source.

Remember that the more resistors you use, the more evenly distributed the heat, so use as many as you can within reason. Whatever your choice, try to keep the sum of the resistance within an ohm or so of the prescribed formula.

Constructing the electronics for the dew cap is simple. Space the resistors evenly around the inside of the dew cap, keeping them far enough away from the bottom edge so they won't touch the corrector cell when the dew cap is in place. Poke holes in the dew cap with a large needle or sharp awl. Make the holes large enough for the resistor leads to pass through when the leads are installed from the inside. Push the leads of the resistors through from the inside of the tube and lay them flat against the outside.

Join each lead to its neighbor, twisting the ends together securely. (Leave the last two leads free to join to the cable you'll run to the power source.) If the leads aren't long enough to reach each other, use a short piece of wire of similar gauge to act as a jumper. A professional job calls for soldering the leads together, but this isn't absolutely necessary: twisting the leads *securely* and laying them flat against the tube will do. On the other hand, when one of the twisted joints fails, you'll wish you had soldered the connections.

Now wrap several turns of electrical tape around the tube, completely covering the leads and resistors and leaving only the two unattached leads exposed. Further turns of wide duct tape will seal everything nicely. I plug my dew cap into my car's cigarette lighter by connecting the dew cap leads to a regular lamp cord with a male lighter plug (from Radio Shack) on the end. I also installed a thumbwheel switch and a fuse holder (with a 15-amp fuse) on the cord. A medium-size pair of alligator clips can be substituted for the lighter plug, which allows you to connect the system directly to your car battery. Just make sure you've added a fuse to the system (they're available at Radio Shack and can be placed at a point somewhere along the cable) to ensure safety.

There you have it: An inexpensive, good-looking, functional dew cap for less than $10 and a Saturday afternoon's worth of elbow grease. What more could the owner of a Schmidt-Cassegrain telescope ask for?

---

*Harry Hammond is an active astronomy hobbyist who lives in Mashpee, Massachusetts. His favorite activity is astrophotography, and he is currently building a collection of galaxy and cluster photographs he's taken.*

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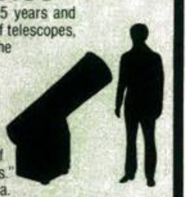

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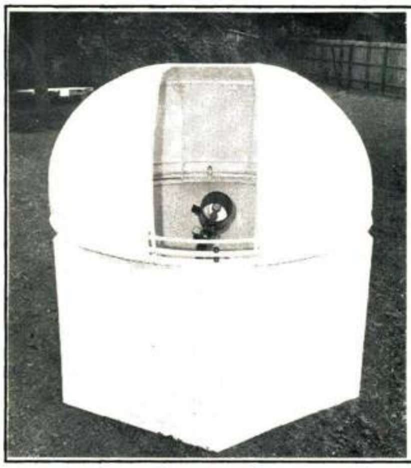

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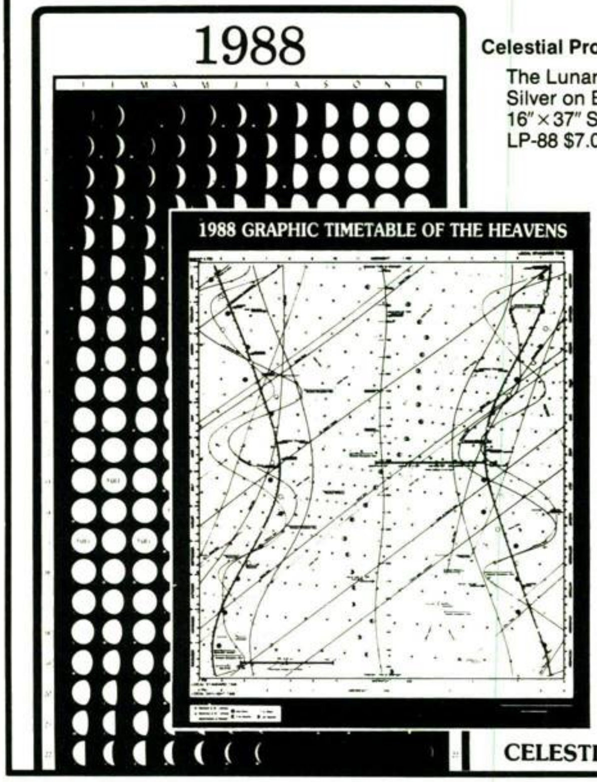

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Photography in Astronomy

# SR-V 3200: The Superfilm from Konica

When Konica introduced SR 1600 color negative film last year, astrophotographers hailed the film's high speed, excellent color sensitivity, and low reciprocity failure. Perhaps even more important is that they praised SR 1600 because it has remarkably fine grain for so fast a film.

When we at ASTRONOMY heard that Konica planned to release a new color film rated at ISO 3200, we were very excited. The higher speed would keep exposure times short. But could a film so fast prove useful for astrophotography? In the past, ultra-high speed films have proven to be virtual washouts because of excessive graininess.

To find out whether SR-V 3200 could pass muster, we obtained sample rolls of the new film from Konica and exposed them under the same conditions and with the same type of equipment many astrophotographers use.

Here's what we found: Although SR-V 3200 film is twice as fast as SR 1600, it is no grainier and may be slightly *less* grainy than its slower cousin. SR-V 3200 offers less intrinsic reciprocity failure than SR 1600 and can be hypersensitized or chilled to reduce reciprocity failure still further. In color sensitivity, SR-V 3200 is well suited to deep-sky photography, efficiently recording both galaxies and nebulae. Although SR-V 3200 lacks the high contrast of color slide films, it is capable of recording faint nebular detail to the sky-fog limit.

### Test Shots

Assistant editor Jeff Kanipe and I shot test exposures on SR-V 3200 both hypersensitized and "straight." Jeff shot wide-angle shots with a 50mm lens at f/2.8 and "close-up" shots with a 200mm f/4.5 telephoto lens. I made longer exposures of a variety of deep-sky objects, comparing hypered and unhypered SR-V 3200 and SR 1600 films with a 6-inch aperture f/5 Newtonian reflector and a 135mm f/1.8 telephoto lens stopped down to f/2.8. Jeff used an Astro Kits camera tracking platform for his photographs; I used a Byers 812 mounting for tracking my homemade telescope.

We asked Jack Marling of Lumicon to hypersensitize two test rolls of SR-V 3200 on an experimental basis, and we purchased two test rolls of hypersensitized SR 1600 for comparison testing. All of our films were processed and printed at Foto Fast, a local one-hour film-processing store. We chose commercial "garden variety" processing to insure that our results would reflect what any ASTRONOMY reader could hope to achieve.

In addition to our in-house tests, astrophotographer Jack Newton shot two test rolls of SR-V 3200 and sent us his test prints. Jack had compared exposures made at ambient temperature with exposures made with a cold camera on his 20-inch f/5 Newtonian reflector.

After all the test film had been processed and printed, I evaluated the negatives and prints, tabulating negative quality against exposure time, focal ratio, negative density, test conditions, and final print quality. We then asked photographer Ken Novak of Communigraphics to prepare custom prints from our best negatives to publish with this article.

### Exposure versus Negative Density

Over an astonishingly wide range of exposure — as many as five or six stops — prints from the photofinisher looked nearly the same. Modern automatic printing machines compensate for variations in negative density to produce the "best" print from any negative. However, close inspection of such prints reveals differences in graininess, color rendition, image sharpness, and color contrast, which depend on the density of the negative and hence the exposure it received.

We exposed test sequences from 1 minute at f/8 to 16 minutes at f/2 to determine what exposure and what negative density give the best images. The results are summarized in two tables, Under- and Overexposure with SR-V 3200 and Recommended Exposure Times, on this page. I examined the negative sequences and found the shortest exposure that gave acceptable results, the exposure that gave best image quality, and the best tradeoff between exposure time and image quality.

For most astrophotography I recommend exposures that give either "acceptable" or "optimum-time" results. Doubling the "optimum-time" exposure to make a "best-image" exposure usually isn't worth the time required, and dou-

## Recommended Exposure Times

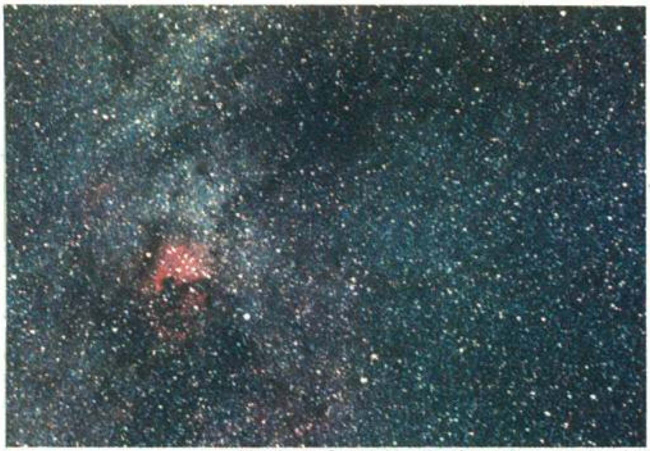
| Film | f/2.8 | f/5 |
|---|---|---|
| SR 1600 | 4-8 min | 20-60 min |
| SR 1600 Hypered | 2-4 min | 10-20 min |
| SR-V 3200 | 2-4 min | 10-30 min |
| SR-V 3200 Hypered | 1-2 min | 5-15 min |

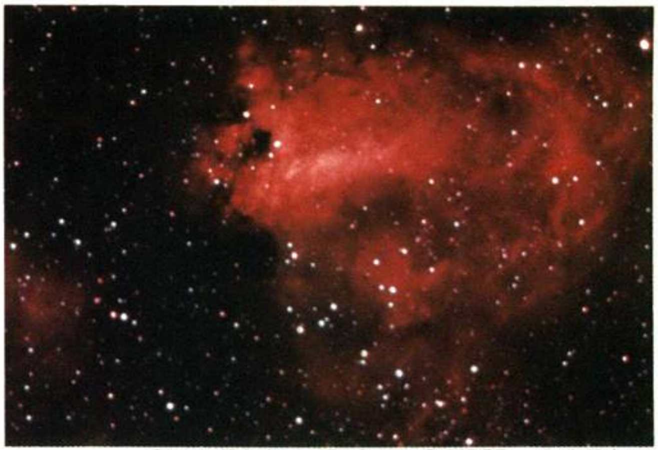
**The times listed are for "acceptable" and "optimum-time" exposures to record nebulosity in a clear, dark, night-time sky (i.e., sky in which the Milky Way is readily visible). The first number in each pair is the acceptable exposure; the second is the optimum-time exposure.**

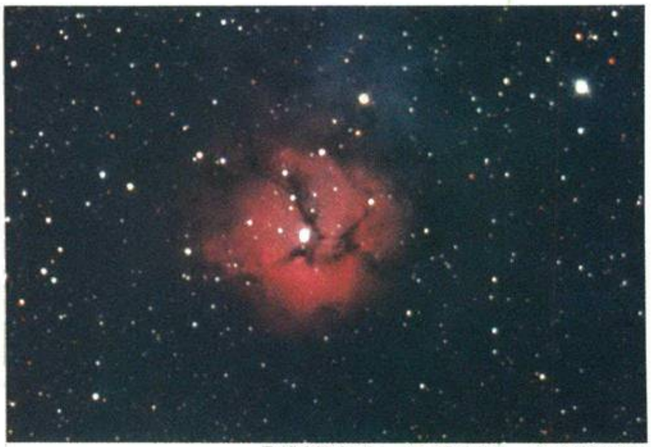
## Under- and Overexposure with SR-V 3200

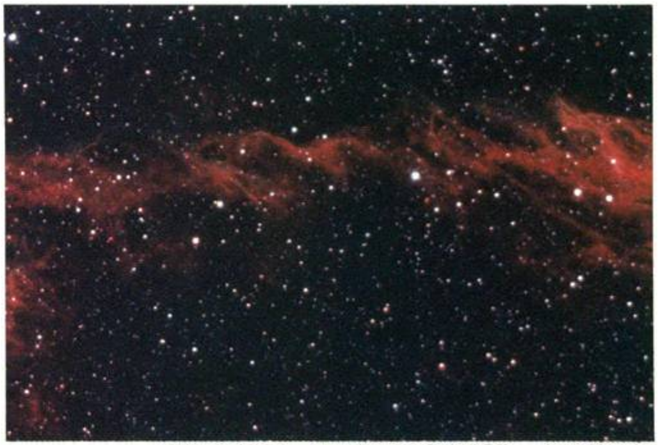
| | |
|---|---|
| −3 Stops | Very grainy, green, poor color saturation. |
| −2 Stops | Grainy-looking, greenish brown image cast. |
| Acceptable | Image slightly grainy with good tone range. |
| Optimum Time | Fine-grain appearance, good blue rendition. |
| Best Image | Image is sharp, crisp, contrasty, colorful. |
| +2 Stops | Image is sharp, crisp, contrasty, colorful. |

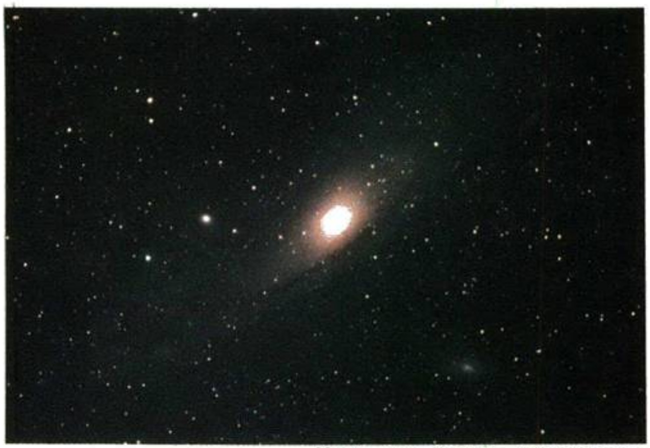
**Graininess is not a problem with SR-V 3200 color film, as demonstrated by this photo, which was enlarged twelve times. The photograph of the Lagoon Nebula is a 20-minute exposure made with a 6-inch f/5 reflector; the film was neither hypered nor cooled. Photo by Richard Berry.**

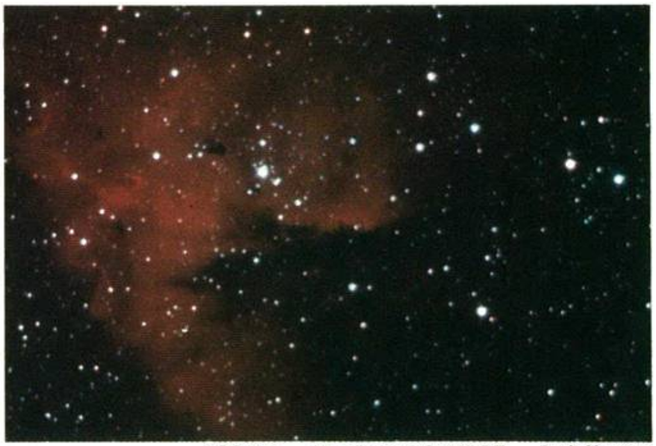

Northern Cygnus — 4 minutes — Jeff Kanipe

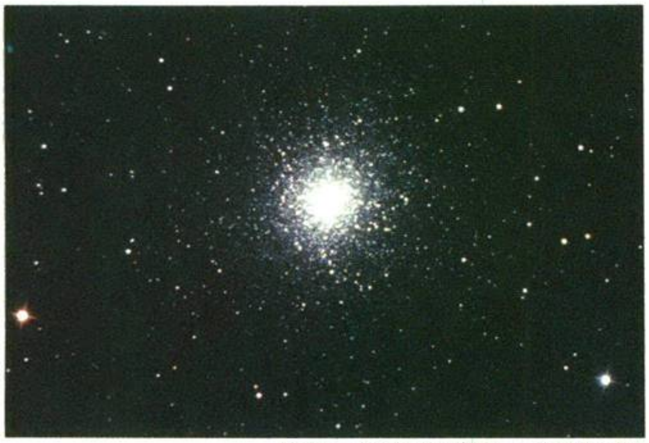

Omega Nebula — 15 minutes Cold/LPF — Jack Newton

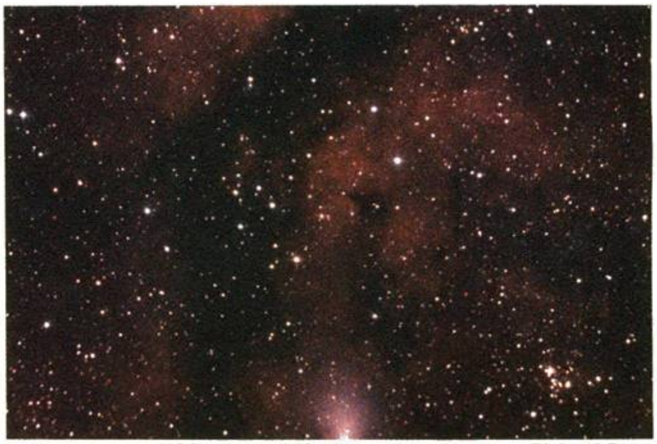

Trifid Nebula — 7 minutes — Jack Newton

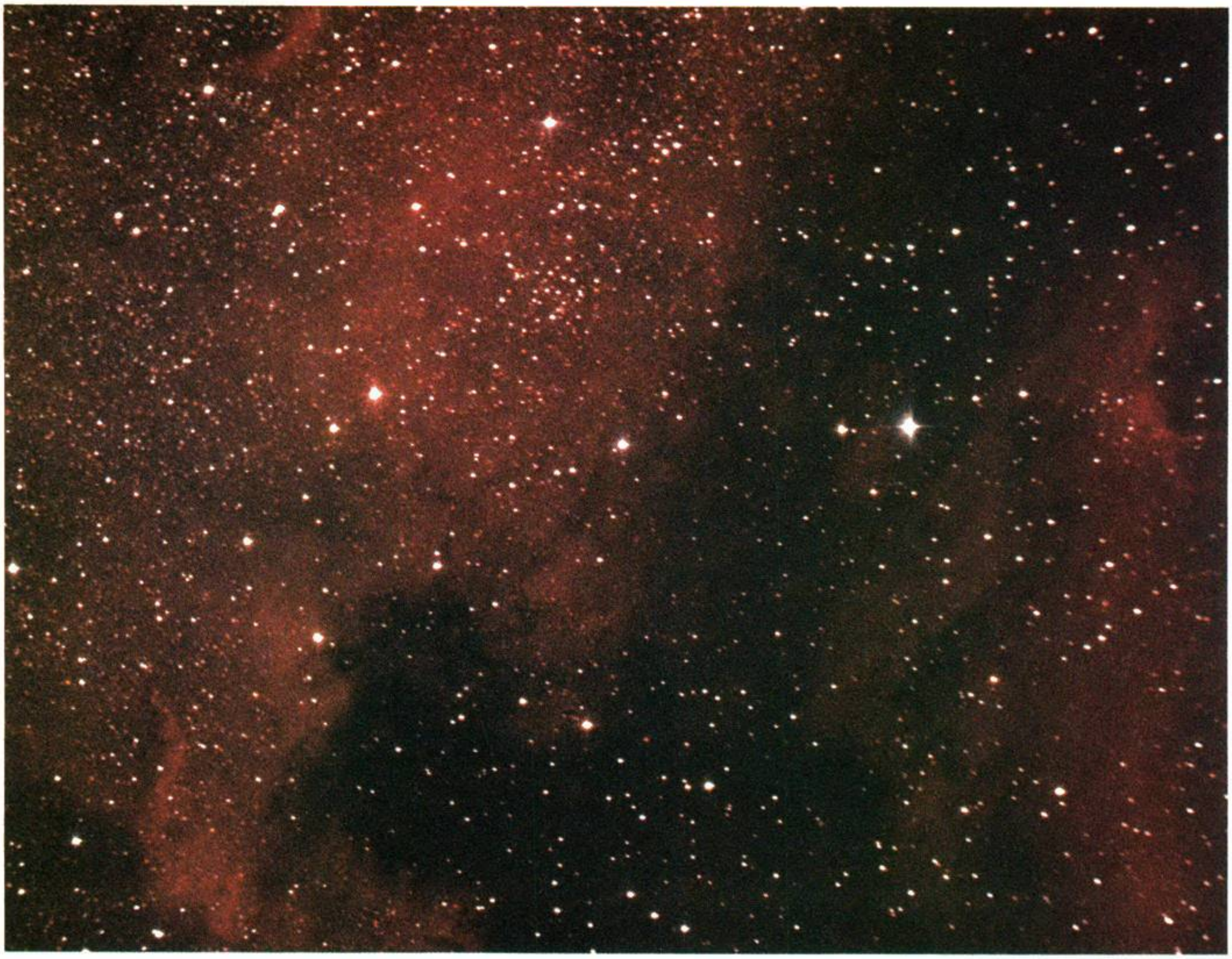

Cygnus Loop — 30 minutes Cold/LPF -- Jack Newton


M-31 — 20 minutes — Richard Berry


NGC-281 — 16 minutes Cold/LPF — Jack Newton


M-13 — 6 minutes Cold — Jack Newton


NGC-6910 and IC 1318 — 20 minutes — Richard Berry



**Detail in the North America and Pelican nebulae stands out in a 20-minute exposure with a 6-inch f/5 reflector. Exposures of 5 and 10 minutes also record the nebulae, but the pictures are grainier and the color is poor. Photo by Richard Berry.**

bling the exposure generally means halving the number of objects you can shoot per night.

Color negatives are difficult to judge for density. Nevertheless, the following guidelines may help you determine where your first test negatives fall in the SR-V 3200 exposure sequence.

To the eye the frame of an "acceptable" negative stands out clearly from the unexposed background, but the exposed area does not look dark. It is easy to read fine print three or four inches behind the negative. This is the exposure to use if you want to shoot the largest number of subjects per session.

An "optimum-time" negative looks quite dark, but fine print is still readable through it. (For the professional photographers in our readership the sky background of an "optimum-time" negative has a diffuse density of 0.6 above base and fog.) This exposure produces good image quality with only half the exposure time required for the very best image quality.

**Fast, versatile, and not too grainy, SR-V 3200 responds well to a variety of deep-sky challenges. Exposure data below each picture indicate whether a cold camera or light pollution filter (LPF) was used. Jeff Kanipe used a 50mm f/2.8 camera lens, Richard Berry used a 6-inch f/5 Newtonian, and Jack Newton used a 20-inch f/5 Newtonian.**

A "best image" frame is sufficiently dark to obscure fine print behind the negative. As it receives more exposure, SR-V 3200 becomes less grainy, sharper, and more contrasty. I recommend a "best image" exposure for recording *extremely* faint diffuse nebulae; only then is the additional time required justified.

Prints made from exposures several stops denser than the "best image" exposure are virtually indistinguishable from the "best image" exposure. SR-V 3200 also tends to retain detail in overexposed parts of the image; even in long exposures the core of the Lagoon Nebula did not get burned out.

Negatives exposed two stops less than "optimum-time" appear quite thin but may yield good prints provided the subject is a bright object with strong color, such as the Lagoon Nebula, so the background sky can be printed dark.

If your negatives are three stops underexposed, the loss in image quality is sufficiently great that you should increase your exposure time, switch to a faster camera or telescope, or use hypered or chilled film if you are not already doing so.

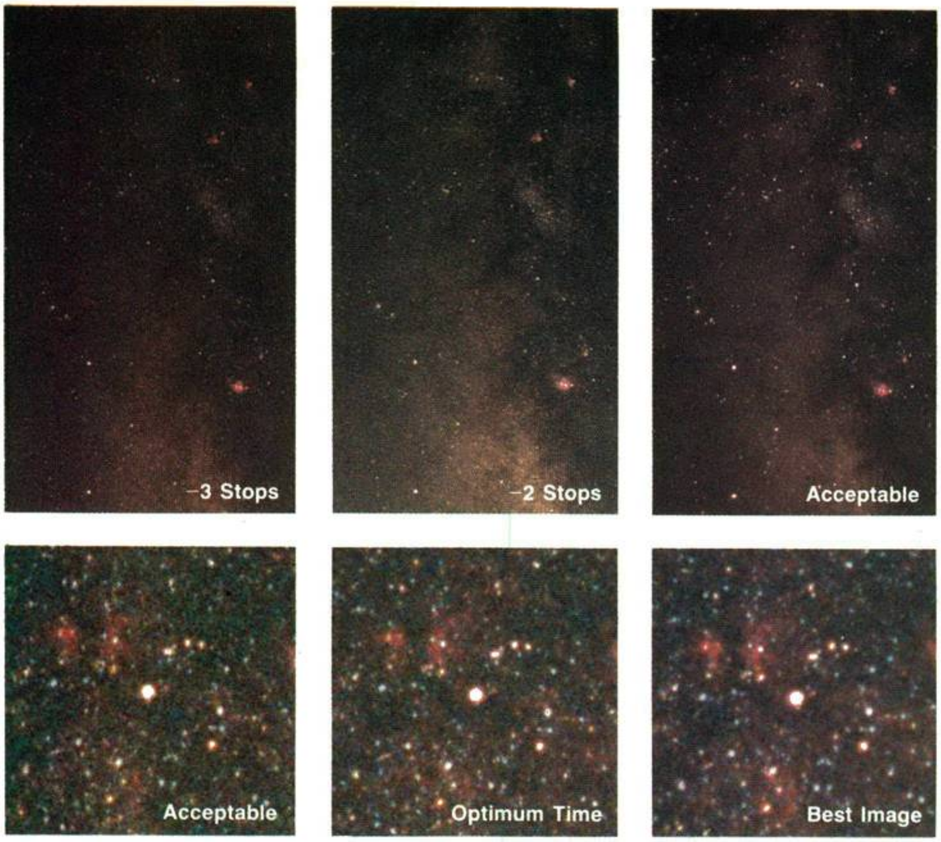
### Hypered versus Unhypered

We tested SR-V 3200 and SR 1600 both straight out of the box and hypersensitized. Hypersensitizing involves placing the film in a heated air-tight chamber in forming gas, a nonflammable mixture consisting of 8 percent hydrogen and 92 percent dry nitrogen. Hypering drives oxygen and water out of the emulsion; both impede the formation of a stable latent image in the film during exposure.

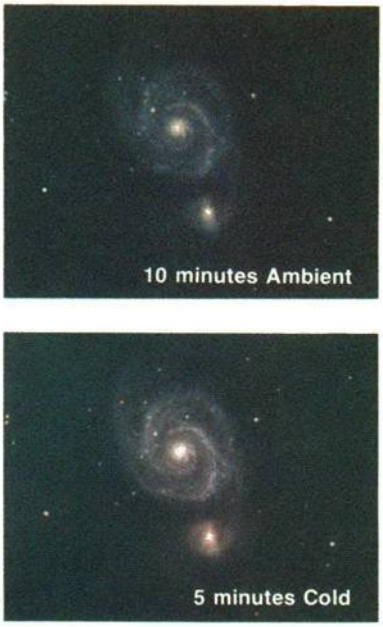
The sensitivity of hypersensitized SR 1600 film was approximately tripled in 10-minute exposures; with hypersensitized SR-V 3200 the sensitivity was roughly double that of unhypered film.

Both films yielded bluer-looking prints when they were hypersensitized and appeared to be somewhat more sensitive to "blue" celestial objects such as galaxies. This difference may occur because the blue film layer is more strongly affected by the treatment or because the film is stained or fogged to produce a blue cast.

Hypersensitized film has a short shelf


-3 Stops
-2 Stops
Acceptable
Acceptable
Optimum Time
Best Image

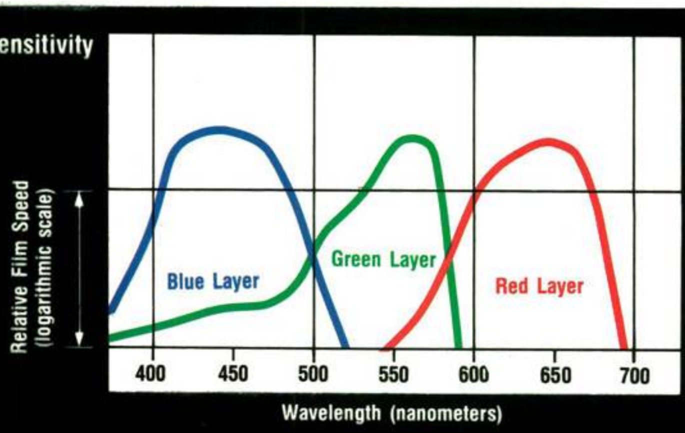
Exposure sequences show how image quality varies with negative density. Top row: Underexposure results in graininess, low contrast, and poor color. Bottom row: Photos enlarged by fifteen times show how color and sharpness improve as exposure increases from "acceptable" to "best image." Milky Way photographs by Jeff Kanipe.


10 minutes Ambient
5 minutes Cold

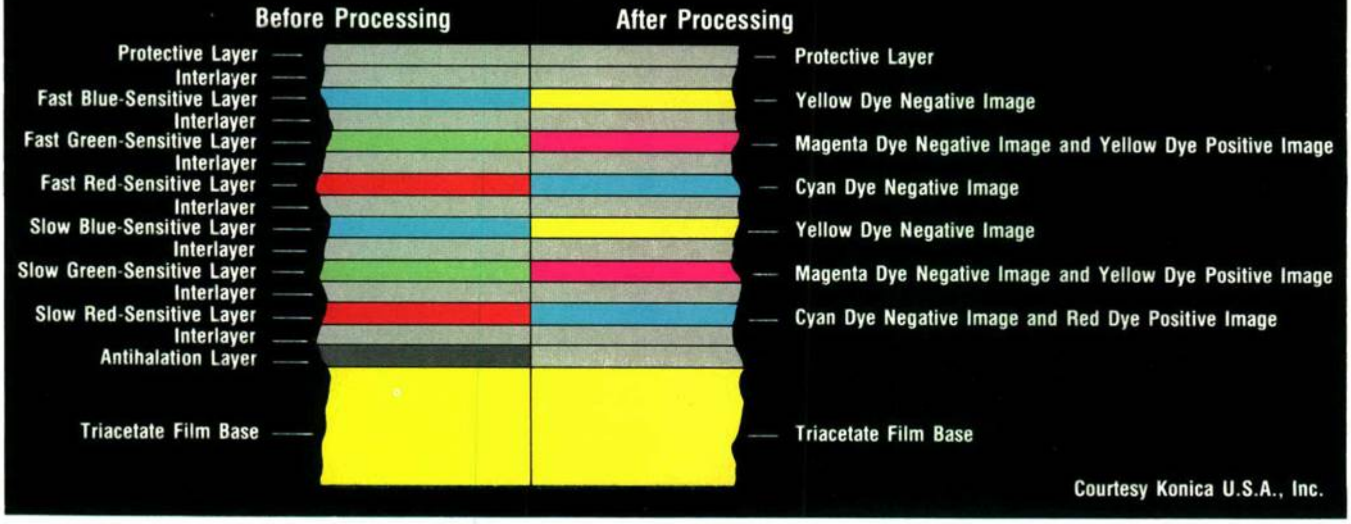
SR-V 3200 responds well to chilling in a cold camera. In the photos above, the 5-minute cold-camera exposure shows more detail and better color balance than the 10-minute exposure at ambient temperature. Photos of M-51 by Jack Newton with a 20-inch f/5 reflector.

## Characteristics of Konica SR-V 3200 Film

Color Sensitivity



Emulsion Cross Section


Before Processing
After Processing
Protective Layer
Interlayer
Fast Blue-Sensitive Layer
Interlayer
Fast Green-Sensitive Layer
Interlayer
Fast Red-Sensitive Layer
Interlayer
Slow Blue-Sensitive Layer
Interlayer
Slow Green-Sensitive Layer
Interlayer
Slow Red-Sensitive Layer
Interlayer
Antihalation Layer
Triacetate Film Base
Protective Layer
Yellow Dye Negative Image
Magenta Dye Negative Image and Yellow Dye Positive Image
Cyan Dye Negative Image
Yellow Dye Negative Image
Magenta Dye Negative Image and Yellow Dye Positive Image
Cyan Dye Negative Image and Red Dye Positive Image
Triacetate Film Base

Courtesy Konica U.S.A., Inc.

life. Once it has been treated, the emulsion may lose its desirable characteristics if it is exposed to warm, moist air. Lumicon ships hypersensitized film in sealed cassettes with drying agent inside and recommends storing hypered film in a freezer. Because of a run of poor weather during testing, we stored one roll of hypersensitized SR-V 3200 in a camera body at room temperature for a week without noticeable degradation.

With both SR 1600 and SR-V 3200, hypering is worth the effort and/or expense. Because hypering doubles or triples the effective film speed, you can shoot two or three times as many subjects per night (by using shorter guiding times) or shoot the same number (but get better image quality through longer exposures).

### Cold Camera versus Ambient Temperature

Cold cameras were the astrophotographer's most powerful tool before hypersensitizing became common and still is a powerful technique when properly applied. Dry ice is normally used to cool the film. The chief disadvantage of chilled-emulsion photography is that atmospheric moisture condenses or freezes on cold surfaces. To avoid this, photographers place the film in a vacuum (necessitating an air-tight camera body with a window and a vacuum pump) or against a thick Plexiglas "plug" (requiring plug warm-up, drying between exposures, and a special camera body).

Cooling film to −20° to −40° C nearly eliminates reciprocity failure by inhibiting decay of the latent image. Jack Newton exposed SR-V 3200 at temperatures near +20° C in a specially built cold camera. His pictures demonstrate that SR-V 3200 records more detail in a 5-minute exposure chilled than in a 10-minute exposure at ambient temperature — and gives better color balance too.

### How Konica Did It

Both SR-V 3200 and SR 1600 are the result of advances in silver halide crystallization technology made by Konica. By tailoring the shape and size of the light-sensitive crystals, the company's chemists can tailor films to whatever characteristics they desire. Kodak's new T-Max films use similar technology; they employ tablet-shaped grains Kodak calls T-grains.

SR-V 3200 and SR 1600 films have six sensitized layers: three large-grain high-speed layers sensitive to red, green, and blue light and three fine-grain low-speed layers sensitive to red, green, and blue. On exposure to light the high-speed layers build up an image fastest and then as the exposure to light increases, the slower layers build up an image. This fast-layer/slow-layer structure may account for the improvement in image quality with longer exposures: when the slow, fine-grain layers kick in, they form a crisp and detailed image.

### Enhancing SR-V 3200 Images

SR-V 3200's greatest strengths lie in grabbing an image in a short exposure time, its tolerance for under- and overexposure, and rendering the sky in realistic color. What techniques should astrophotographers use to enhance its strengths?

First and foremost, expose the film to its optimum density. We found that a typical one-hour film processing lab can make impressive astronomical prints from a good, properly exposed negative. Prints made from underexposed negatives look washed out, green or brownish, and very grainy.

Second, when you get a negative that deserves better than a machine-made 3x5-inch print, find a custom photo lab to print it larger or learn how to do color enlarging and make your own prints. The custom prints made for this article are considerably more impressive than the 3x5-inch machine-made prints. You might request Cibachrome prints; this material yields much snappier prints than ordinary photo paper.

If you want to produce slides rather than prints, "dupe" the negatives onto Kodak 5072 film. This film is made for producing slides from color negatives. The only equipment you'll need is a slide duplicator, color compensation filters, and a tank for processing the 5072.

Once you're reaching the sky-fog limit routinely, make some test shots through a light-pollution filter. The Lumicon Deep Sky filter blocks yellow and green light from streetlights and billboards while transmitting blue and red light from celestial objects. Although the filter distorts overall color balance somewhat, you'll record more nebulosity on the film. Shooting through a filter doubles or triples exposure times with SR-V 3200.

One rather crude way to snap up flat negatives is to copy them on a contrasty slide film. If you're a home darkroom buff, try copying your negatives on Kodachrome and then printing those "enhanced" negatives. This will certainly introduce color distortion, but the gain in contrast may be just what you're looking for.

Two techniques probably do not work: push-processing and exposing hypered film in a cold camera. Pushing color negative film only raises the stain level, according to Konica emulsion chemists. Hypering and chilling both operate by preventing decay of the latent image during exposure; combining the techniques does not further enhance the effects.

SR-V 3200 is a revolutionary film. Its extreme speed makes shorter exposures of deep-sky objects possible, and that means easier guiding, easier setups, and more photos per night than previously possible.

A grainy film by ordinary standards, SR-V 3200 nevertheless offers finer grain than any other super-fast film. It responds well to hypersensitizing and chilling. Both techniques generate speed gains of two to three times, and both techniques improve the film's response to blue light.

Its high sensitivity to both red and blue light makes SR-V 3200 well suited for photographing stars, star clusters, nebulae, and galaxies. Correctly exposed, SR-V 3200 records faint nebular detail to the sky-fog limit. In short, SR-V 3200 is a winner.

*— Richard Berry*

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## Stores That Carry SR-V 3200

ARIZONA
Phoenix: Wilson Camera.
CALIFORNIA
Los Angeles: Bel Air Camera, Hooper's Camera (North Hollywood), Monte's Camera (Whittier), Powell Camera (Covina). San Diego: George's Camera. San Francisco: Photographic Supply, Osaka-Ya Camera, Wentling's Camera (Concord), Danville Camera (Danville), Kauffman's Camera (San Mateo), Palmer's Camera (Berkeley).
COLORADO
Denver: Englewood Camera (Englewood).
FLORIDA
Bradenton: Bradenton Camera. Jacksonville: Brandon's Camera. Miami: Pittman Photo, Worldwide Photo. Sarasota: Sarasota Camera Exchange.
GEORGIA
Atlanta: Showcase Photographic.
ILLINOIS
Chicago: Standard Photo, Camera City.
INDIANA
Evansville: Schmitt Photo.
KANSAS
Kansas City: C & J Photo (Overland Park). Topeka: Wolfe Camera.
MASSACHUSETTS
Boston: W. B. Hunt (Melrose), Nobles Camera Shop (Hingham).
MICHIGAN
Detroit: Camera Mart (Pontiac), Camera Center (Grosse Pointe).
MISSOURI
Kansas City: Elko Camera. Springfield: Hoag Camera. St. Louis: St. Louis Photo, Jefferson Camera.
NEW JERSEY
Newark: Mall Camera/Camera One. Pomton Lakes: Chris Camera.
NEW YORK
Buffalo: Delaware Camera. New York City: Willoughby's, Cambridge Camera.
NORTH CAROLINA
Burlington: Camera Corner. Charlotte: Camera World. Greensboro: Carolina Camera. Raleigh: Sam Bass Camera. Winston-Salem: Carolina Camera.
OHIO
Cleveland: Camera City, Dodd Photo.
OKLAHOMA
Oklahoma City: Lawrence Photo.
PENNSYLVANIA
Pittsburgh: Foto Hut. Philadelphia: Camera Shops of Broomall (Broomall).
TEXAS
Dallas: Industrial Photo Service (Rowletti), Warehouse Photographic (Carrollton). Houston: Skylark Camera (Pasadena).
UTAH
Salt Lake City: Inkley's Photo Center.
VIRGINIA
Richmond: Bob's Camera.
WASHINGTON, D.C.
Snap Shops Photo, Embassy Camera, District Camera Shop, Sommers Camera.

## Obtaining SR-V 3200 by Mail

Consumer Sales Associates carries Konica products, including SR-V 3200, and sells by mail order. The address is: 17 Randolph Avenue, Franklyn Square, NY 11010. Phone: 800-367-7553, in New York (516) 326-7604. Shipment is usually same day via UPS.

# ASTRONOMY
# Reviews

## Radio Astronomy Redefining the Universe

*The Invisible Universe Revealed* by Gerrit Verschuur, (Springer-Verlag, 1987), ISBN 0-387-96280-8, 262 pages, hardcover, $19.95

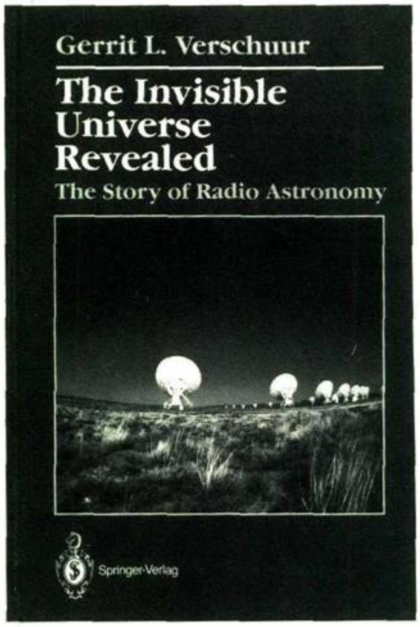
Gerrit Verschuur's new book on the history and progress of radio astronomy is a complete rewriting of one Verschuur published in 1974. Over the intervening thirteen years, which represent about one quarter of the entire history of radio astronomy, the field has changed profoundly. In one sense, radio astronomy doesn't really exist as a separate branch of astronomy anymore. Like other astronomy disciplines — infrared, ultraviolet, x-ray, and gamma-ray astronomy — the discoveries made in radio astronomy have been assimilated by the field as a whole (though radio astronomers still remain largely a distinct group).

*The Invisible Universe Revealed* is divided into six parts. The first explains what radio astronomy is about — what radio waves are, how they are generated, received, and so on. The second, third, and fourth parts deal with radio sources in the universe, from extragalactic objects such as quasars to stellar objects (SS 433, for example) to the solar system (the Sun and Jupiter).

Part five examines radio cosmology and the search for extraterrestrial life. The last part reviews the history of radio astronomy, covering instrumental and theoretical development and prospects for the future. The book ends with fourteen short appendices (on atoms, scientific notation, the electromagnetic spectrum, etc.), a too-brief reading list, and a terse index.

Verschuur has staked out a lot of territory to cover in less than three hundred pages and the treatment of each topic therefore is brief. I find the emphasis lies a little more strongly on observable phenomena than on explanations of what astronomers are observing. For instance, in the sections on extragalactic sources, the author spends much time explaining the observations that place limits on what the "central engine" of quasars can be. Yet he then devotes comparatively little space to explaining what models have been devised for these central sources and how they might work.

After dealing with the most distant objects (quasars, radio galaxies), Verschuur turns to the Milky Way. Outlining the discovery of our Galaxy's central source in the early 1930s, he explains how radio observations can peer behind the intervening dusty curtains to form a picture of the Galaxy's core. Then we look at the more common galactic radio sources — and supernova remnants and emission and planetary nebulae. Pulsars were discovered by a radio telescope and radio signals have contributed the most to understanding the nature of pulsars. The 21-cm "hiss" of interstellar neutral hydrogen opens up the structure of our galactic home and, looking a short way outside it, details the structure of nearby spiral galaxies. The signals from interstellar molecules — water, ammonia, alcohol, to name just a few — betray an astonishingly complex chemistry in the clouds along the Galaxy's spiral arms.



More locally, radio noise comes from the Sun (from flares and sunspots), and Jupiter's magnetosphere interacts with Jupiter's moon Io to send off bursts of radio emission in ways that are still not well understood. Saturn also broadcasts in the radio, though less intensely than Jupiter. In the solar system, radar has played an active part in advancing planetary science — from the early studies of the Moon's surface texture to Mercury's rotation period to mapping Venus through its clouds from Earth.

The sixth and last part of the book divides the history of radio astronomy into four phases — birth, identity crisis, discovery, and consolidation. At birth no one knew what this "wireless astronomy" was all about. Astronomers knew nothing of electronics and radio engineers knew no astronomy. It took until World War II for radio astronomy to make headway, for right afterward the field blossomed, fertilized by abundant stockpiles of war-surplus electronics.

The identity crisis came in the 1950s and early 1960s. Radio was here to stay, but how its results related to those of optical astronomy was not at all clear. For a while it looked as if both astronomies had their own separate objects to look at and had little in common. Even the radio astronomers couldn't always agree on what they were detecting.

Then came the deluge of discoveries. Verschuur aptly names 1960-1975 as radio astronomy's golden age. This is when "quasar" and "pulsar" became words that Madison Avenue could assume ordinary people would recognize. Many large instruments, such as the Jodrell Bank 250-foot dish, came into service. Interferometry gave positions that soon became good enough for aiming optical telescopes and many optical-radio identifications were made. Interstellar molecules and magnetic fields were detected and measured. Radio jets, bipolar outflows of gas from stars, radio polarization, and masers followed.

By the mid-1970s most of the radio universe had been inventoried. What remained to be done, and still does to this day, was the job of filling in the blanks, understanding mechanisms, and using carefully worked out details to build larger models that (hopefully!) mimic physical reality. The easiest part is over — now comes the task of trying to understand what makes the universe tick. All in all, it's a grand and glorious story and Verschuur tells it with great panache.

The illustrations are superb. They are up to date, well done, and unless you've been scanning the professional literature, most of them will be unfamiliar. (It's a shame they're only in black and white.) They give a feeling resembling that of roughly a generation ago, when the first good photos started coming out of the then-new 200-inch telescope. Books and magazines of the early 1950s were filled with crisp photographs showing beautiful and strange celestial objects made newly visible. These pictures defined the optical universe for us. I think we are about to see the same thing happen again with the new radiographs from the VLA and other high-resolution instruments.

Already I suspect the picture of the two-lobed Cygnus A radio galaxy (done at the VLA) is going to become a classic found in every textbook. The same goes for the image of the Cassiopeia A supernova remnant. Both radio photos, as detailed as optical ones, are wonderful — you need no imagination whatever to see those lobes squirting out of the core of Cygnus A or the billowy surges of ionized gas in the Cassiopeia A supernova remnant.

None of this is lost on Verschuur, by the way. He makes a point late in the book of telling you to turn back to these images and explore them with your imagination. It's supremely important, he says, and he's right: While the universe is immeasurably vast, unless we make that essential imaginative leap of involvement, we're just bored parade watchers gazing dully from the curb.

As a rapid survey of a large, technical subject, this book is unexpectedly strong in stressing the human aspects of astronomy — and it is much the better for it. Yet despite the earnest efforts of the appendices, this is not a book for beginners, because it assumes more background than most newcomers to astronomy can be expected to have. On the other hand, I think it works very well for anyone already knowing some astronomy who wants a good summary of what the "radio universe" contains and an interesting perspective on our understanding of it.

*— Robert Burnham*

## Binocular Book Needs Focusing

*Exploring the Night Sky with Binoculars* by Patrick Moore, (Cambridge University Press, 1986), ISBN 0-521-30756-2, 203 pages, hardcover, $19.95.

The glossy dust jacket is quite attractive. Standing against a background of softly glowing stars and globular clusters is Patrick Moore, the esteemed British astronomy popularizer. With binoculars poised, the veteran author appears ready to sample all the astronomical delights within binocular range.

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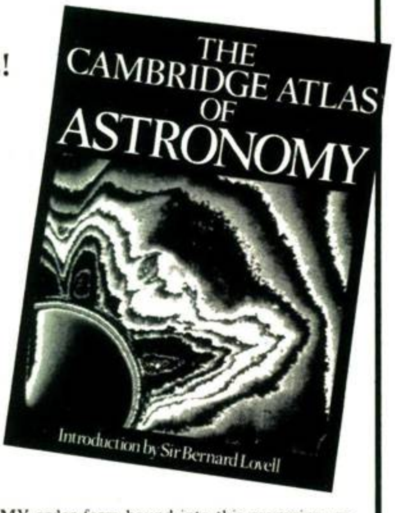

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Those who have never aimed binoculars at the night sky might easily assume that this is the perfect guide book, offering a way to deftly explore the appealing scattering of stars overhead. The title states it. The cover photo infers it. And the stature of the well-known author seems to guarantee it.

Unfortunately the beginning observer will have rough going if he reads the book under this assumption. The opening chapters offer superficial descriptions of some of the major elements in observational astronomy: galaxies, stars, and solar system bodies. Moore describes the constellations and their historical origins, the magnitude system, and stellar evolution and classification.

Next the reader is introduced to double and variable stars. Several finder charts for these fascinating stellar denizens are included, but the map scales are too big, so little information is given about where in the host constellation an observer should look. All we are given are the object's field and the designations of adjacent stars. The text is accurate and interesting, but unless the reader already knows the constellations, he will be utterly lost and disappointed.

Moore uses a folksy, first-person style that is at once engaging and informal. But reading the book is reminiscent of attempting to learn from a lecturer who knows his subject so well he doesn't bother to explain the more difficult concepts.

Chapters six and seven at the heart of the volume consist of all eighty-eight constellations arranged alphabetically, each accompanied by explanatory text and small line-and-dot diagrams. Moore chose not to employ the usual constellation patterns found in most star charts. Bootes, for instance, is patterned not like the familiar kite or ice cream cone outline but instead more closely resembles Orion.

The author explains that his "linking lines" are quite arbitrary. He even points out that "Sagittarius has no distinct shape. Some people have likened it to a teapot, though I have never been able to make out why."

In an attempt to make the book useful anywhere in the world, two reference maps are included. One is centered on the north celestial pole and the other is centered on the south celestial pole. They would be easy to use if the observer were located at either the North or South pole; however, an uninitiated observer at other latitudes will find either map difficult to use because no horizon is provided. Furthermore, an observer in the Northern Hemisphere who attempts to relate constellation patterns on the reference map to the individual constellation diagrams will find that any object south of 0° declination will appear to be upside down.

In places the book is sloppily edited. One example occurs on page 53. Moore states: "Locating the south celestial pole is not really difficult (I have given detailed instructions on page 00), though there is no bright star close to it."

The book's final pages are devoted to solar eclipses, the Moon, the planets, comets, and what the author calls "shooting stars."

Patrick Moore has written many fine astronomy books. This one, though it contains some helpful tips and worthwhile background information on many of the celestial objects that can be observed through binoculars, appears to be trading on Moore's name and reputation too heavily. The cover blurb indicates that the casual observer and those cultivating a more serious interest will find this volume tremendously helpful and encouraging. I disagree.

— *Gail Clark*

## Comet Halley Keeps on Giving

*Images of Comet Halley: A Slide Set*, (European Southern Observatory, ALB-Geschaftsstelle, c/o Stefan Bohle, Danziger Strasse 4, D-7928 Giengen/Brenz, West Germany, 1986), twenty slides, includes text, $25.00.

The European Southern Observatory's slide set comprises some of the best electronic and photographic images of Comet Halley made with ESO's complement of telescopes at its Southern Hemisphere site near La Silla, Chile.

The twenty slides, taken between December 10, 1982, and April 30, 1986, provide a visual record of Halley's apparition as well as a demonstration of the various observing techniques used in modern astronomy. The slide set is also accompanied by a text that interprets what the viewer is seeing in each slide and how each slide was produced.

The slides are chronologically arranged. The set begins with two images of the faint, inbound comet, taken December 10, 1982, and January 14, 1983, when Halley was still beyond Saturn's orbit. Other slides illustrate the development and changes in Halley's ion and dust tails, the bursts of dust around the comet's nucleus, and the notable "disconnection event," when the ion tail separated from the coma and dissipated into space, which is captured over three slides. These last three slides are negatives and reveal remarkable tail structure that would not be as noticeable in positive images. The last slide is an exposure taken April 30, 1986, as the comet passed south of Alpha Crateris on its way out of the inner solar system.

The accompanying text is fairly technical and undoubtedly intended for a college-level audience. The writers of the text assume the viewer has been exposed to basic spectroscopy and cometary behavior, as well as to some image processing techniques and professional astrophotography. Nevertheless, on this rather advanced level, ESO's slide set succeeds very well.

— *Jeff Kanipe*

## Software

*Solarsim*, (Interstel Corp., P.O. Box 57825, Webster, TX 77598, 1987), solar system simulation software for IBM PC, XT, and AT, $29.95

*Solarsim* is a multipurpose software package that offers programs for displaying the relative positions of solar system bodies in three dimensions and as a conventional star map. In addition to printing sky coordinates to aid in finding a faint outer planet, asteroid, or comet in the real sky, *Solarsim* can also plot the future positions of planets and asteroids.

The main attraction of *Solarsim* is its ability to depict the motion of solar system bodies either from Earth or from any selected point in near space. However, *Solarsim*'s star maps suffer from the limitations of computer speed and resolution. Unless you have a hot AT, the software runs slowly because it frequently accesses disk files to plot star positions.

*Solarsim* cannot display planet positions for dates prior to A.D. 1, so you can't go hunting for interesting alignments prior to this time.

Nevertheless, its three-dimensional specialty should make it attractive to educators, and its plotting capability will be of interest to serious planet observers.

— *James Bailey*

## Space

*Jane's Aerospace Dictionary* by Bill Gunston, 2nd edition, (Jane's Publishing, Inc., 1986), ISBN 0-7106-0365-7, hardcover, 565 pages, $39.95.

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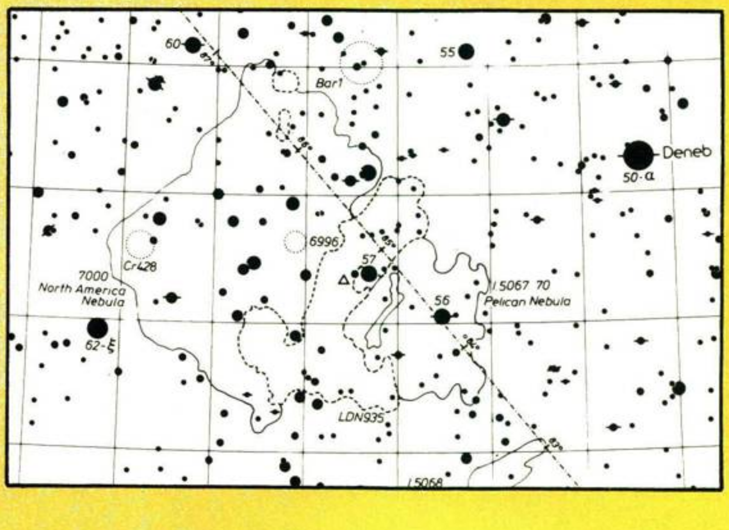
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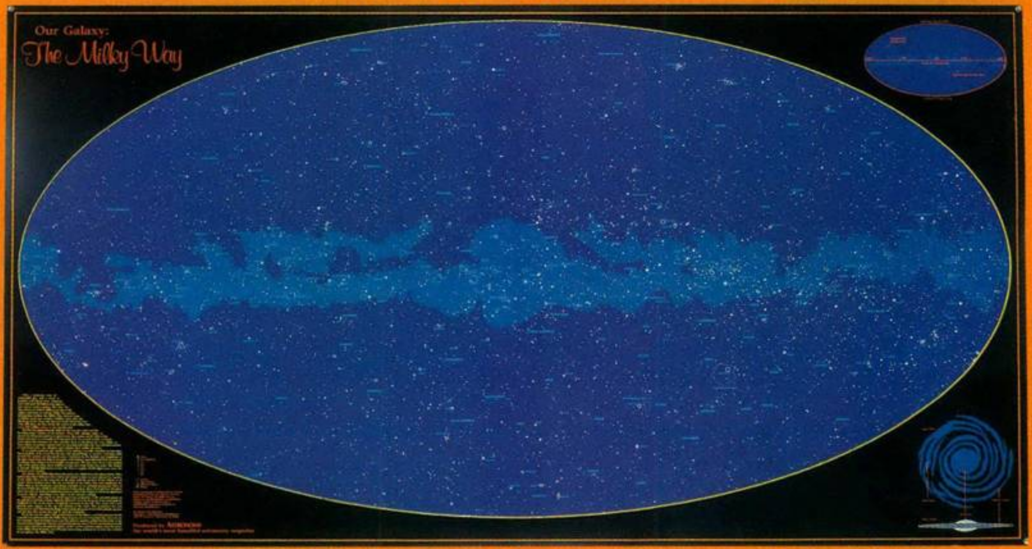

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# ASTRONOMY
# AstroNews

## Comet Bradfield: A Northern Sky Showpiece

**A new comet designated Comet Bradfield 1987s will be visible to the naked eye across the northern Milky Way in the evening sky this fall. Early predictions indicate Comet Bradfield will reach perihelion on November 7.1 UT and should be brightest in late November, when it could shine at magnitude 5 and sport a tail several degrees long. Predicted magnitudes for Bradfield are 7.6 on September 22, 6.6 on October 12, 5.7 on November 1, and 5.4 on November 21, according to the ephemeris generated by Brian G. Marsden of the Smithsonian Astrophysical Observatory.**

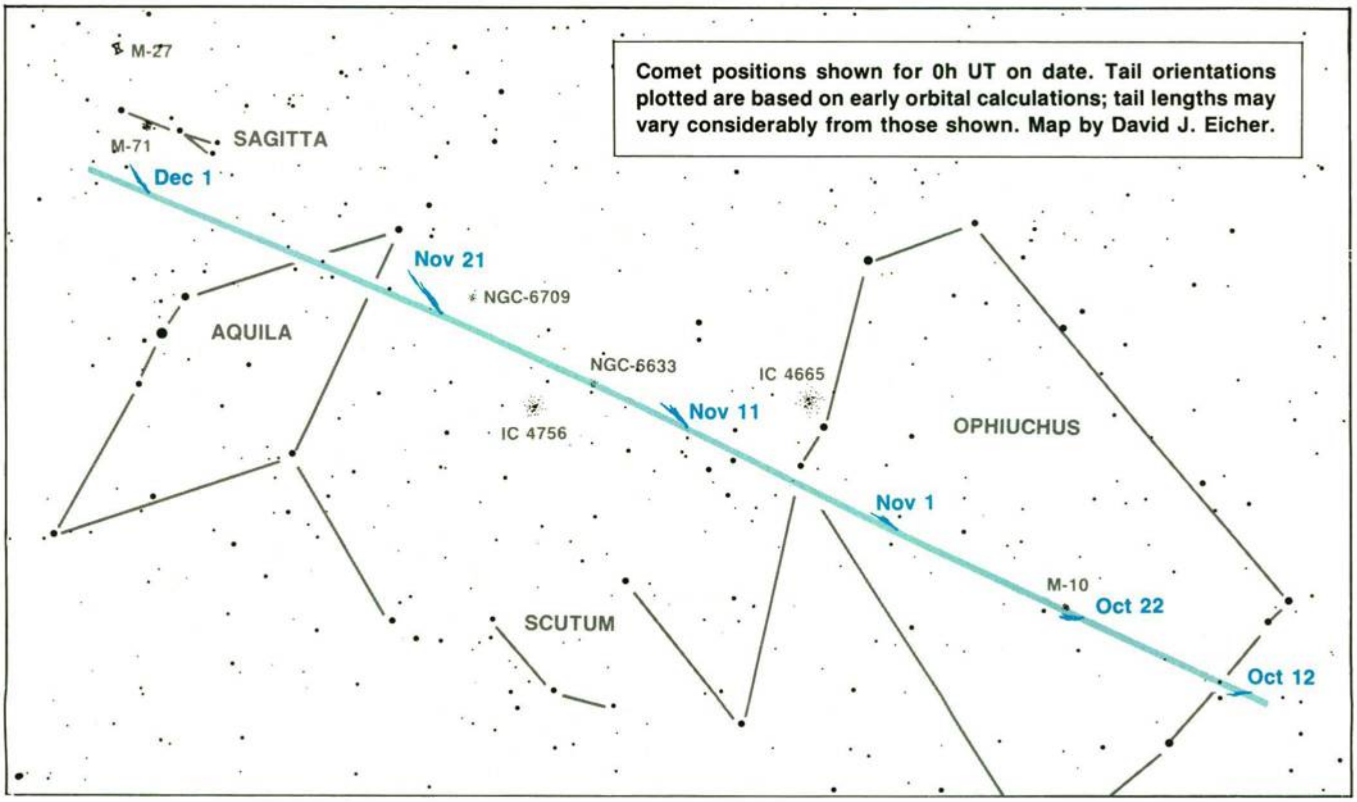
**The map shows a preliminary path for the comet based on early observations of Bradfield's orbit. This path may change slightly as the comet's orbit is refined. This preliminary map allows you to find the comet with binoculars or a small telescope.**

**Around October 21, Comet Bradfield will pass close to the globular cluster M-10 in Ophiuchus. In mid-November the comet will pass between the bright open clusters IC 4665 and IC 4756. At the end of November Comet Bradfield will be situated just south of Sagitta, a few degrees from the bright star cluster M-71.**

**The comet was discovered on August 11, when it was a 10th-magnitude object moving slowly northeast across Hydra. Australian amateur astronomer William Bradfield spotted the out-of-place object, making his thirteenth comet discovery and surpassing all other comet hunters of the twentieth century.**

## Massive Black Hole Discovered in M-31

Using the 3.6-meter Canada-France-Hawaii telescope perched atop Mauna Kea, Hawaii, John Kormendy of Canada's Dominion Astrophysical Observatory recently discovered a massive black hole in the nucleus of M-31, the Andromeda Galaxy. Kormendy measured the Doppler shift of the galaxy's inner nucleus and found that the stars in it orbit at a velocity of at least 143 kilometers per second. This is compelling evidence for the existence of a very large black hole in M-31's center. A similar study by astronomers Alan Dressler of Mount Wilson and Las Campanas Observatories and Douglas Richstone of the University of Michigan came to the same conclusion.



**Comet positions shown for 0h UT on date. Tail orientations plotted are based on early orbital calculations; tail lengths may vary considerably from those shown. Map by David J. Eicher.**

Kormendy is pursuing a new systematic study of the rotation velocities of stars in nearby galaxies with the CFH telescope. The principal targets are disk galaxies because they are plentiful and because many nearby examples are available. Their central bulges also rotate rapidly enough so velocity distributions are close to isotropic.

M-31 was a natural first choice because it is the nearest spiral galaxy to the Milky Way. Kormendy studied spectra of M-31' s center, which indicated that the galaxy's inner core — the region within one arcsecond of the nucleus as observed from Earth — is spinning extremely rapidly. This large velocity and the extremely abrupt falloff of fast rotation outside the one arcsecond radius require the galaxy to contain a massive object in its center some 100 million to 1 trillion times the mass of the Sun. There is only one clear explanation for this much mass in so small an area: an enormous black hole.

## Millisecond Pulsar Discovered in Globular Cluster

A team of British and American astronomers has discovered a pulsar rotating some 327 times per second in the core of globular cluster M-28 in Sagittarius. The pulsar, designated PSR1821-24, is the first of any kind found in a globular cluster, and its presence there strongly supports the theory that such "millisecond" pulsars arise through accretion in binary systems.

The team consists of Shrinivas Kulkarni of the California Institute of Technology, Andrew Lyne and A. Brinklow of the University of Manchester in the United Kingdom, John Middleditch of Los Alamos National Laboratory in New Mexico, and Don Backer and T. R. Clifton of the University of California at Berkeley. The results appeared in *Nature* (July 30, 1987).

Despite the uniqueness of the find, the discovery was not unexpected. After the first millisecond pulsar was discovered in 1982, a number of researchers suggested that such objects evolve from low-mass x-ray binaries. These binary systems consist of one normal star with a mass fairly close to that of the Sun and one compact object — a neutron star if the system forms a millisecond pulsar — that draws matter from its companion. A millisecond pulsar arises when mass from the normal star accretes on the neutron star, which causes the neutron star's rotation rate to dramatically increase. Because low-mass x-ray binaries are more likely to form in the dense, star-packed conditions of a globular cluster, astronomers expected that millisecond pulsars would also form preferentially in globular clusters.

Astronomers David Helfand and T. T. Hamilton of Columbia University and Robert Becker of the University of California at Davis conducted a survey of twelve nearby globular clusters in 1983 with the Very Large Array radio telescope to look for millisecond pulsar candidates. They found just one, located in the core of the 5.8-kiloparsec-distant M-28. Subsequent observations provided strong indirect evidence that this radio source was indeed a pulsar, but the actual pulses remained hidden until now.

Using a new multichannel high-speed data recording system, Lyne and Brinklow observed the object with the 76-meter radio telescope at Jodrell Bank in the United Kingdom. They then sent the tapes of these observations to the American team, who processed them on a Cray-XMP supercomputer at Los Alamos. The researchers found a periodic signal with a period of about 3 milliseconds in one of the channels. Follow-up observations at Jodrell Bank confirmed the presence of a pulsar with a 3.05431449-millisecond period.

One of the more surprising aspects of the discovery is that the pulsar is not in a binary system — its presumed birthplace. Fortunately the conditions that make binary formation likely in a globular also tend to break up the resulting binaries. The researchers offer two scenarios: a rapidly moving cluster star passes close to the binary and disrupts the pair; and an old neutron star is captured after an almost head-on collision with a normal star, and the two stars coalesce following the low-mass x-ray binary stage.

Researchers continue to monitor PSR1821-24 at Jodrell Bank and with the 140-foot telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia. The period of the pulsar appears to be as stable as that of the other millisecond pulsars. This accurate "clock" will provide astronomers with valuable information about the dynamics of the core of M-28. A few years from now the motion of the pulsar across our line of sight should be detectable with this clock, which will allow astronomers to determine the three-dimensional motion of a globular cluster for the first time.

## Space Telescope Amateur Deadline Extended

If you want to submit a proposal for observing time on the *Hubble Space Telescope*, you still have time to get one ready. The Hubble Space Telescope Amateur Astronomers Working Group announced that the deadline for amateur astronomers has been extended from June 30, 1987, to the date of the first shuttle flight, currently scheduled for June 2, 1988.

The Working Group had received 138 proposals by the June 1987 deadline, according to Stephen J. Edberg, chairman of the Working Group.

"Anybody with an interest in astronomy is welcome to submit a proposal," Edberg

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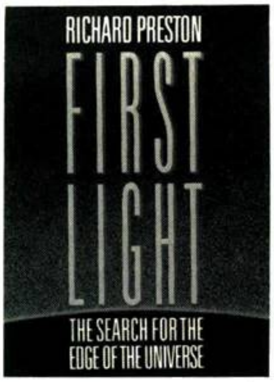

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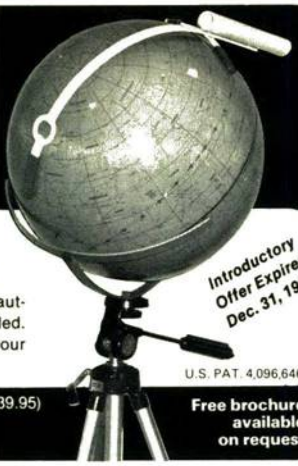

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said. "And not only amateur astronomers but others, like teachers. The only people who *can't* compete are professional astronomers."

After the proposals are received and read, the Working Group asks the amateur astronomers whose proposals present interesting, workable ideas for a more in-depth justification of their project: what they want to accomplish, how they plan to do it, what kind of instruments they'll need, and how much time they'll require, Edberg said.

"They'll need to formalize the proposal enough so we have a fair idea of how they're going to go about accomplishing it," Edberg added.

The Working Group ranks the selected proposals in order of priority. The proposals are then presented in the recommended order to Riccardo Giacconi, director of the Space Telescope Science Institute, who makes the final decision.

For information on submitting a proposal, contact the American Association of Variable Star Observers (AAVSO), 25 Birch Street, Cambridge, MA 02138.

## Large Warp Detected in Spiral Galaxy

The tenuous hydrogen gas enveloping the disk of the spiral galaxy NGC-4013 in Ursa Major is severely warped, according to radio observations by astronomers in the Netherlands. Astronomers hope that a study of this warp, the largest yet detected in the outer regions of a spiral galaxy, will lead to an understanding of gas motions within spirals that cause warping.

Spiral galaxies exhibiting visibly distorted structures in their outer regions — for example, long plumes of ejected gas curling away from the galactic disk — have been recorded in deep-sky photographs throughout most of this century. But it wasn't until the advent of radio astronomy in the 1950s that warps above and below the galactic disks of spiral galaxies were found in the regions beyond the visible disks of spirals. The gas occupying this region consists of neutral hydrogen (HI) atoms. Because neutral hydrogen is not ionized and has a temperature of only a few thousand kelvins, the gas can be detected only by its radio emission at the 21-centimeter line in the spectrum.

In a paper published in *Nature* (July 30, 1987), R. Bottema, G. S. Shostak, and P. C. van der Kruit of the Kapteyn Astronomical Institute, the Netherlands, state that the warp in NGC-4013 begins where the visible disk leaves off and extends about 50 percent beyond the visible disk of the galaxy. The opposite ends of the gas are bent diametrically like the brim of a fedora. Because of a favorable line of sight with the disk of NGC-4013 and the severity of the warp, astronomers easily detected this unusual feature.

According to the astronomers, the large warp in NGC-4013 cannot be sustained by the mass in the visible disk alone. Therefore, the warp must lie in an extended halo of hidden matter. The total HI mass is calculated to be 1.1 billion solar masses.

Approximately 1 percent of all spiral galaxies exhibits warping to some extent. In fact, in the 1950s astronomers discovered that neutral hydrogen in the Milky Way's outer periphery was warped: gas in the direction of Cygnus extends 1 kiloparsec above the plane of the Galaxy, and gas in the direction of Carina extends a similar distance below the galactic plane.

How or why these peculiarities occur is not understood. Photographs of interacting spiral galaxies suggest that tidal forces between systems distort the arms and disks. The severity of the distortion depends on the nearness of the encounter. Near-collisions cause dramatic tidal displacements, while more distant interactions cause symmetrical and less obvious perturbations.

But not every warped spiral is found in the presence of a nearby companion. Thus, other explanations have been advanced, ranging from asymmetries in the mass about the galaxy's rotational plane to infalling gas from outside the galaxy. These latter hypotheses are considered unlikely, however. No doubt further study of NGC-4013 and other similarly perturbed spirals is needed to establish the causes of galactic warping.

## ALPO Celebrates Fortieth Birthday

Last March the Association of Lunar and Planetary Observers celebrated its fortieth year of observing the solar system. The organization was founded in 1947 by Walter H. Haas to improve the communication between active planetary observers. Since then ALPO has developed into an outlet for serious amateur studies of the solar system and has amassed what is probably the most extensive records of lunar and planetary observations made by nonprofessional observers.

Currently ALPO has over seven hundred members, the majority of which live in the United States (twenty members live overseas). About one fifth of ALPO's members are professional or semiprofessional astronomers; the remainder are amateur observers. As expressed by ALPO director John E. Westfall in *The Journal of the Association of Lunar and Planetary Observers* (July 1987), the emphasis of the group is "still on getting out and observing."

A core of the membership regularly supplies observational data on the Sun, Moon, planets, minor planets, comets, and meteors to professional astronomers. Systematic observations in the form of notes, sketches, or photographs are sub-

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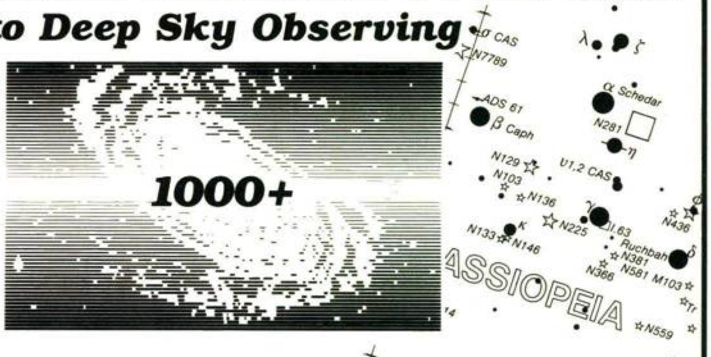

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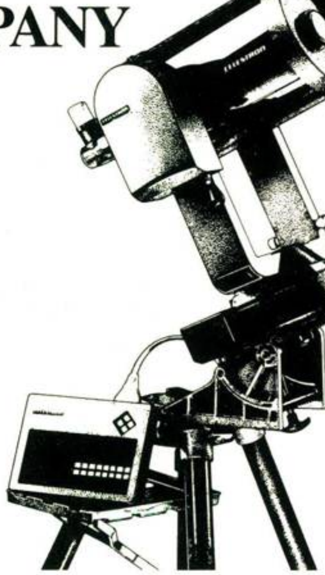

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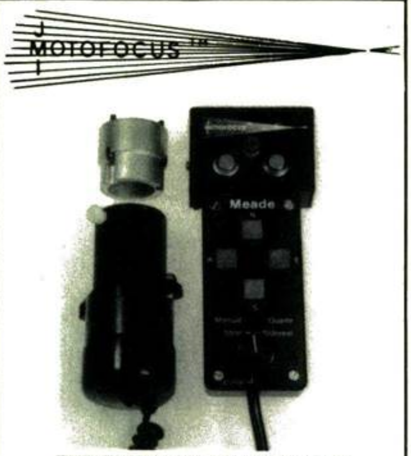

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Information about ALPO membership and activities can be obtained by writing the Association of Lunar and Planetary Observers, Dr. John Westfall, P.O. Box 16131, San Francisco, CA 94116.

## How Bright Are the Local Galaxies?

Astronomers have measured the brightness of six Local Group galaxies with unprecedented accuracy. A study completed in 1986 by Harvard-Smithsonian astronomer Stephen M. Kent produced the first modern, wide-field surface photometry for M-31, M-32, M-33, NGC-147, NGC-185, and NGC-205. The new study provides more accurate measures of these galaxies' surface brightnesses, which when coupled with future analyses of these and other data will yield more accurate masses and estimates of numbers of stars in these galaxies.

Local Group galaxies are important to extragalactic researchers because these galaxies are close enough to show large amounts of detail. But they are so large that traditional photometric equipment captures light intensities from only small parts of the galaxies at one time. The light from these galaxy sections is then mathematically summed and a resulting measure of the entire galaxy determined. However, adding together many sections of galaxy light keeps the possibility for error high.

Kent used a charge-coupled device (CCD) detector to make the new two-dimensional maps of the galaxies' brightnesses. The telescopes Kent used included a 105mm lens, a 90mm Maksutov telescope, an 8-inch f/10 Schmidt-Cassegrain, a 24-inch f/13 reflector, and a single 60-inch f/13 mirror in the Multiple Mirror Telescope. The observations were made at the Whipple Observatory on Mount Hopkins, Arizona. The raw electronic data collected by the telescope/CCD combination was later used to plot the overall light intensity from the galaxies versus the distance from their centers, creating a profile of surface brightness for each galaxy.

The resulting profiles represent a refinement of the brightness data for Local Group galaxies. The new V magnitudes produced thus far in the study are slightly brighter than the currently accepted values. Kent derives a V magnitude of 3.28 for M-31, compared with 3.45 listed in the authoritative *Second Reference Catalogue of Bright Galaxies* (*RC2*). Kent's V magnitude for M-32 is 8.06, slightly brighter than the *RC2* value of 8.21. On the other hand, the low surface brightness elliptical NGC-147 has a Kent V magnitude of 9.52, which agrees with the *RC2* figure of 9.5.

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**9th Annual Astronomy Jamboree,** Custer Institute, Southold, Long Island, New York. Contact: Tom Carey, Vanderbilt Planetarium, Centerport, Long Island, New York 11721. Phone: (516) 757-7501.

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**Deep South Regional Stargaze** (sponsored by the Jackson Astronomical Association), Percy Quin State Park, McComb, Mississippi. Contact: Jeff Sommers, 414 Woody Drive, Jackson, MS 39212. Phone: (601) 982-2388 days, (601) 372-2275 evenings.

**October 24**
**Astronomy Rendezvous and Conference 1987** (sponsored by the Twin City Amateur Astronomers), Illinois State University, Normal, Illnois. Contact: Carl J. Wenning, Physics Department Planetarium, Illinois State University, Normal, IL 61761-6901. Phone: (309) 438-8758.

**October 28-31**
**Great Lakes Planetarium Association Meeting,** Merrillville, Indiana. Contact: Greg L. Williams, Merrillville Community Planetarium, 199 East 70th Avenue, Merrillville, IN 46410.

**December 21-22**
**International Seminar on Ancient Astronomies** (sponsored by the B. M. Birla Planetarium), Hyderabad, India. Contact: B. G. Sidharth, Director, B. M. Birla Planetarium, Adarsh Nagar, Hyderabad, 500 463, India.

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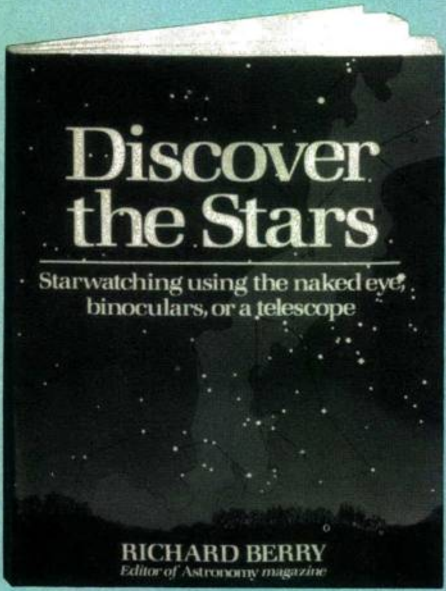
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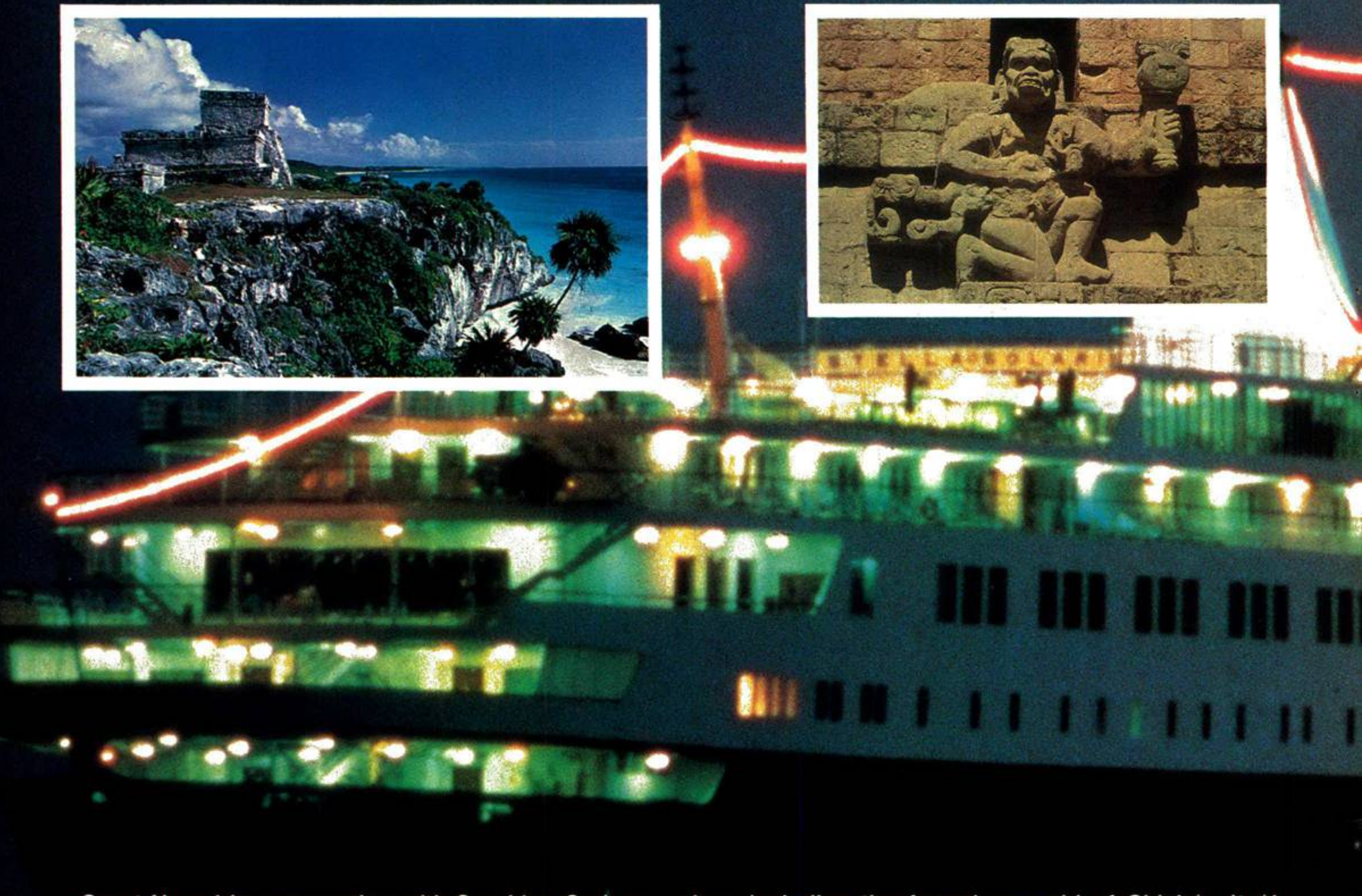

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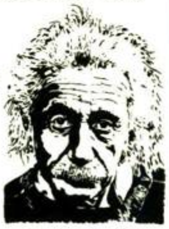

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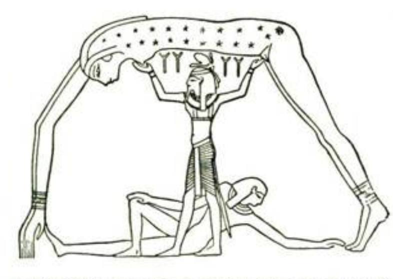

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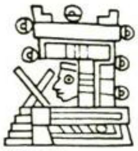

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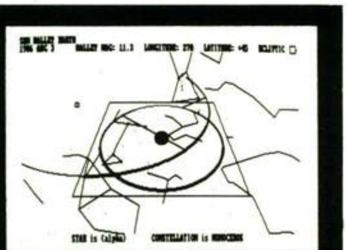

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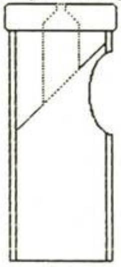

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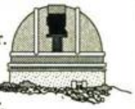

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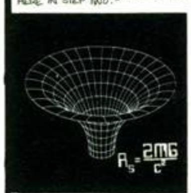

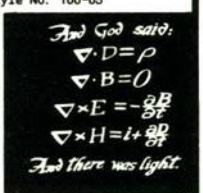
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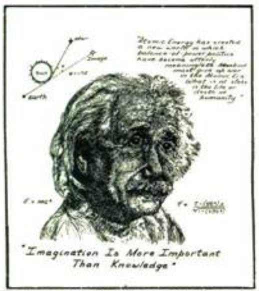
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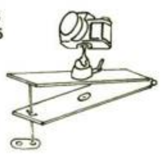

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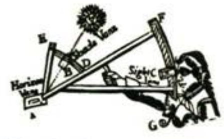

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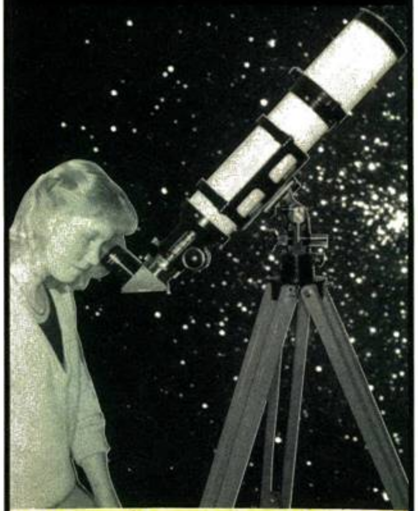

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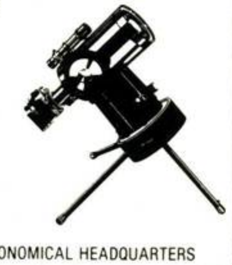

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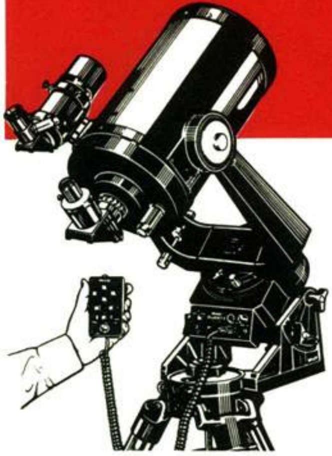

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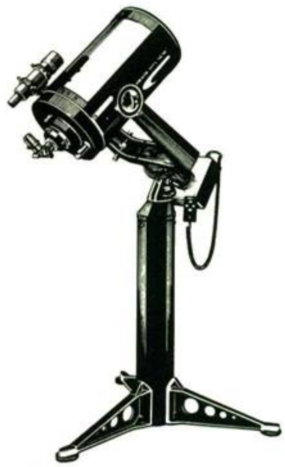

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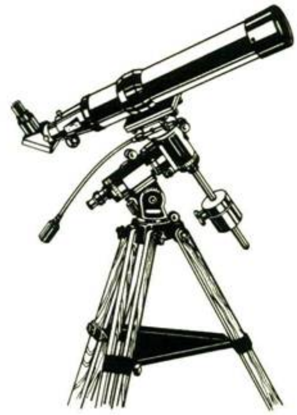

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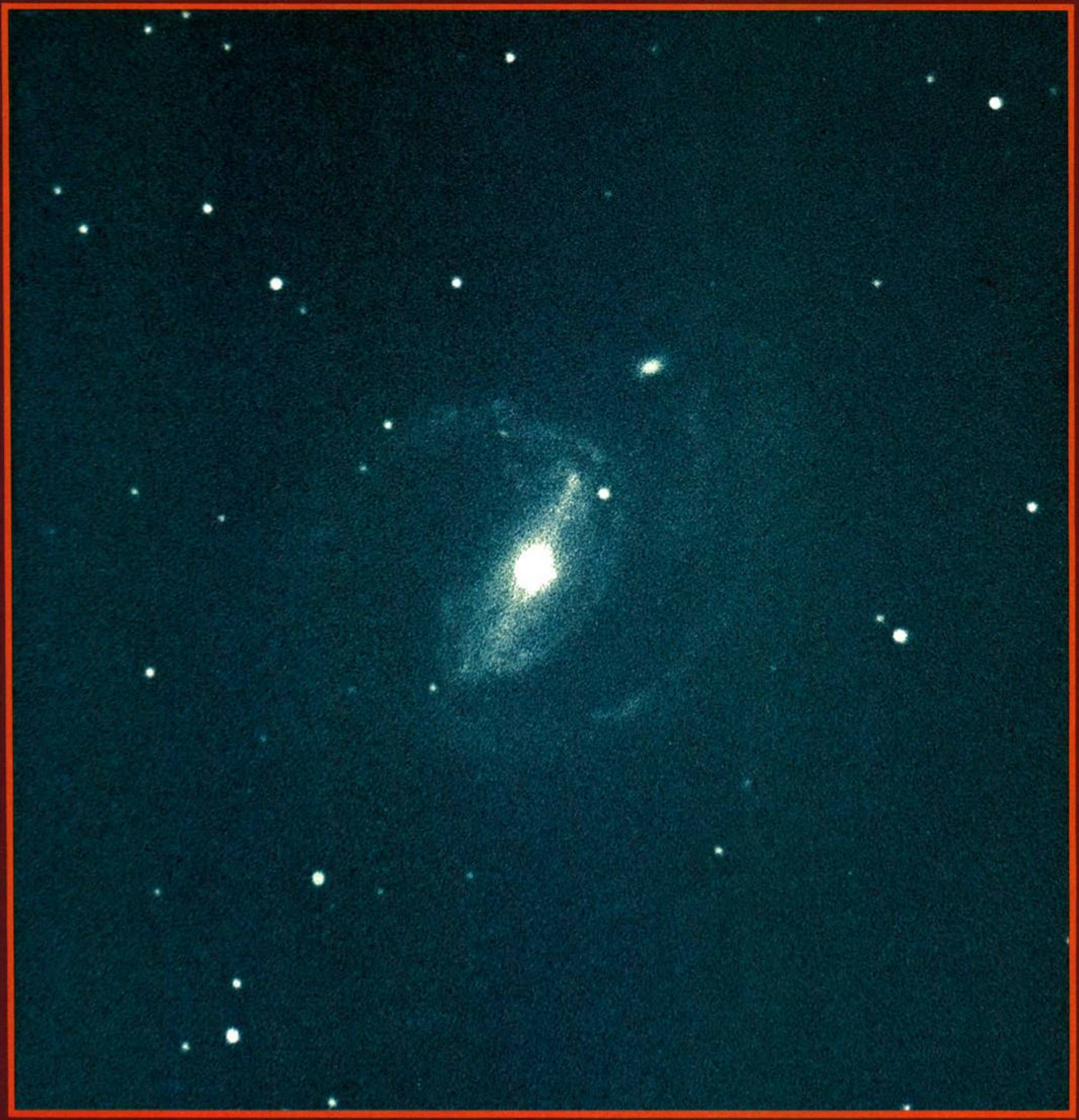


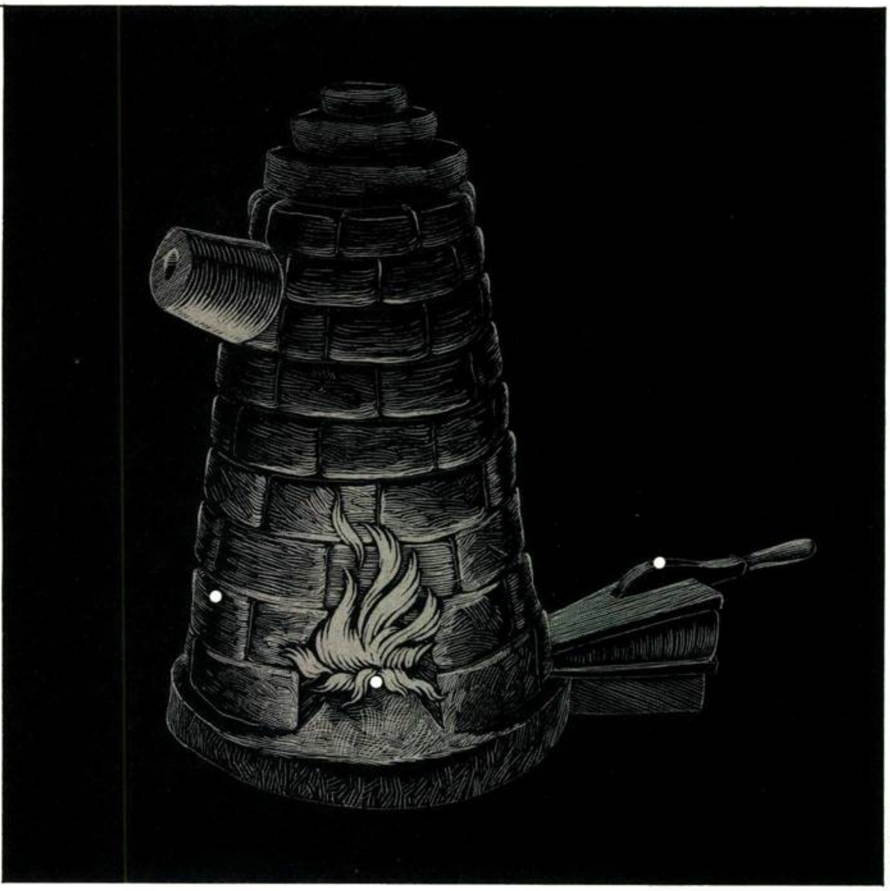
Above: NGC-1097 is the second brightest galaxy in Fornax and one of the best examples of a barred spiral for observers with small telescopes. A 6-inch instrument at medium powers shows the faint arcs of the galaxy's spiral arms.

Far left: One of the brightest planetary nebulae in the southern sky, NGC-1360 is visible in a 2-inch scope as a bluish oval haze surrounding an 11th-magnitude central star.

Left: NGC-1049, barely visible in backyard telescopes as a faint "out-of-focus star," is the brightest globular cluster belonging to the Fornax dwarf galaxy. Ironically the Fornax dwarf itself has such a low surface brightness it is invisible in backyard telescopes. Photos by Martin C. Germano.

# Fornax

## For Fornacis



Keith Ward

**Fornax** the Furnace is a relatively small, squarish constellation lying far enough away from the galactic equator that it contains primarily galaxies. Most of these galaxies are faint objects in small telescopes that even on a dark night will challenge the optical quality of your mirror and the ability of your eye to perceive subtle details. With persistence, however, you'll be able to spot detail in several of the Fornax galaxies.

Perhaps the prettiest galaxy in Fornax is the barred spiral **NGC-1097**, an object glowing at magnitude 9.3 and spanning 9.3′ by 6.6′. To find this galaxy, use a low-power eyepiece and aim your finder scope at the bright double star Alpha (*α*) Fornacis. Move 5° southwest to equally bright Beta (*β*) Fornacis, and then continue to a point just over 2° north-northwest of Beta. You should see a bright nebulous glow in the telescope's field of view. (If you don't, try slowly sweeping around this area and see if you don't run across the galaxy.)

Once you've found NGC-1097, increase your telescope's magnification to something like 12x per inch of telescope aperture and study the galaxy in detail. NGC-1097 is one of the best barred spirals in the sky, because it is bright and oriented nearly face-on. With a small telescope you should see a bright, round nucleus surrounded by an oval-shaped halo of slightly fainter nebulosity. Through this halo runs a long, thin rectangular nebulosity, visible in 6-inch scopes on nights of good transparency. This feature is NGC-1097's "bar," the characteristic feature of barred spirals. If you have an 8-inch or larger scope, you may see faint semicircular extensions on the bar's ends. These extensions represent light from the galaxy's spiral arms. Keen-eyed observers with large telescopes will see a tiny detached patch of light 2′ northwest of the galaxy's northern spiral arm. This is NGC-1097A, a tiny, 13th-magnitude elliptical galaxy.

Some 4° south-southwest of NGC-1079 on the other side of Beta Fornacis lies a faint and extremely unusual globular star cluster. Because its magnitude is 13.0 and its disk only 24″ across, **NGC-1049** appears as a pale spot of gray light in a 6-inch scope. When the seeing isn't terrifically steady, this cluster appears like an out-of-focus star or a small, colorless planetary nebula, though actually NGC-1049 is an enormous globular cluster located some 170 kiloparsecs away in a Local Group galaxy called the **Fornax dwarf galaxy**. Discovered at Harvard College Observatory in 1938, the Fornax dwarf is one of several tiny elliptical galaxies scattered throughout our Local Group. It is one of the smallest galaxies known, contains about fifty times as much mass as a typical Milky Way globular cluster, and measures only 2 kiloparsecs across. The Fornax dwarf has such a low surface brightness that it is well beyond the reach of backyard telescopes. Yet, ironically, its brightest globular cluster, NGC-1049, is readily visible in moderate-sized instruments.

In addition to an elusive dwarf Local Group galaxy, Fornax contains a full-fledged galaxy cluster. The so-called Fornax Galaxy Cluster contains eighteen bright galaxies and at least ten faint galaxies compressed into a 6°-diameter circle; most members lie between 20 and 25 megaparsecs away. Located near the heart of the cluster is **NGC-1380**, a lenticular galaxy with a blue light magnitude of 11.1 and dimensions of 4.9′ by 1.9′. To find this galaxy, aim your finder scope toward the bright triangle of stars f, g, and h Eridani. From g Eridani move 3° due west and very slightly north. This should place you on NGC-1380 and the heart of the Fornax cluster.

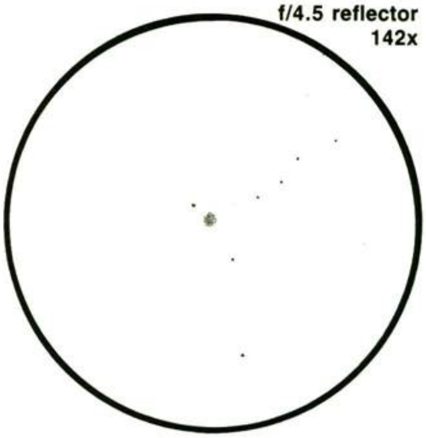
With a low-power eyepiece centered on NGC-1380, you may notice several other smudges of light, especially if you have an 8-inch or larger telescope. It is possible to see nine galaxies in a single 1°-field: NGC-1380, NGC-1374 (a blue magnitude 12.4 elliptical), NGC-1379 (a blue magnitude 12.3 elliptical), NGC-1381 (a blue magnitude 12.5 lenticular), NGC-1386 (a blue magnitude 12.1 spiral), NGC-1387 (a blue magnitude 12.0 lenticular), NGC-1389 (a blue magnitude 12.6 elliptical), NGC-1399 (a magnitude 9.9 elliptical), and NGC-1404 (a magnitude 10.3 elliptical).

Lying about 1° southwest of the main group is another member of the Fornax cluster, the large face-on barred spiral **NGC-1365**. NGC-1365 shines at magnitude 9.5 and measures 9.8′ by 5.5′, which make it one of the brightest galaxies in the area and easily visible as a luminous haze in small telescopes. The bar structure and spiral arms of NGC-1365 are

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

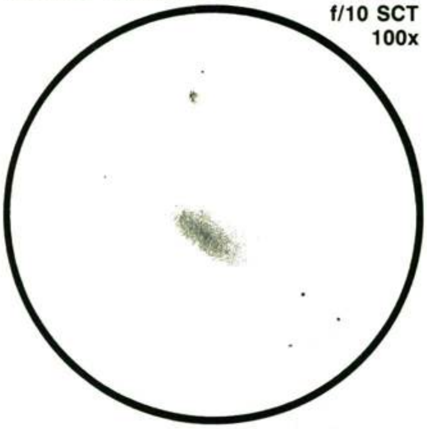
### NGC-1049

17.5-inch
f/4.5 reflector
142x



### NGC-1316/17

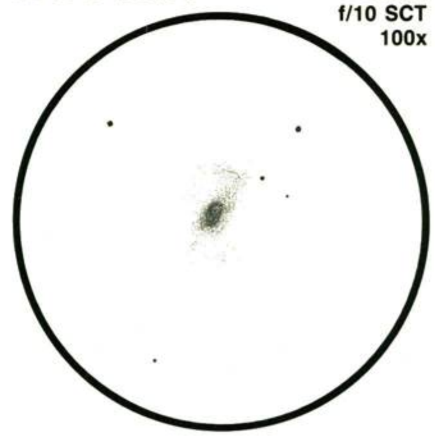
8-inch
f/10 SCT
100x



visible in backyard telescopes, although they can't be seen as easily as those of NGC-1097. A 6-inch telescope shows NGC-1365 as a small bright knot of nebulosity (its core), surrounded by a uniformly illuminated halo of faint nebulosity. A 10-inch telescope shows the bar structure easily and on good nights reveals the galaxy's subtle spiral structure. A faint star is visible in front of the galaxy's face about 2′ northwest of the nucleus.

### NGC-1097

8-inch
f/10 SCT
100x



Sketches by David J. Eicher

Three more members of the Fornax cluster are impressive objects in small scopes. The first of these, **NGC-1427**, lies about 1° northeast of the cluster's center, diametrically across from NGC-1365. NGC-1427 has a blue magnitude of 12.2 and covers 2.8′ by 2.0′ of sky. It is an elliptical galaxy, visible in a 4-inch telescope as a faint oval patch of nebulosity. A 10-inch telescope reveals NGC-1427 as an elongated smear of gray light with a hint of central condensation.

The remaining Fornax cluster members lie in close proximity some 3° west-southwest from the cluster center. **NGC-1316** is a bright peculiar barred spiral of uncertain classification. Somewhat resembling the galaxies NGC-5128 in Centaurus and NGC-1275 in Perseus, this object is an unusually dusty galaxy with a disproportionately bright nucleus. NGC-1316 is also an intense radio energy emitter and is designated radio source Fornax A. Telescopically this galaxy appears as a bright round ball of light with a very faint oval halo superimposed upon it. Large telescopes fail to reveal significant detail in this object. About 6′ north of NGC-1316 is the tiny galaxy **NGC-1317**, which appears as a small knot of faint gray light.

More bright galaxies lie to the north. **NGC-1406**, a blue magnitude 12.6 spiral, lies 1° northwest of the 5th-magnitude star Delta (δ) Fornacis. This object is highly inclined to our line of sight and consequently appears as a dim streak of fuzzy light some 4′ long. Large backyard scopes show a bright disk of nebulosity surrounding its center but fail to show detail in the galaxy's arms. The bright spiral **NGC-1255** can be found 3.5° north of Alpha Fornacis. This galaxy shines at magnitude 11.1 and measures 4.1′ by 2.8′ across, so it is easily identifiable in 3-inch telescopes under a dark sky. With an 8-inch scope NGC-1255 looks like a mottled patch of light surrounding a bright, condensed nucleus. A 12th-magnitude star lies 2′ southwest of the galaxy's center.

In the northeastern corner of Fornax are three more galaxies. **NGC-1371** is a blue magnitude 11.5 barred spiral with a bright center and a subtle dust band visible with large backyard scopes. A bright, unequal double star lies about 5′ east of this object. One degree northeast is **NGC-1385**, a magnitude 11.2 spiral easily visible in small scopes. Slightly over 2° south-southeast is the bright barred spiral **NGC-1398**, visible in 4-inch scopes as a large bright circle of nebulosity.

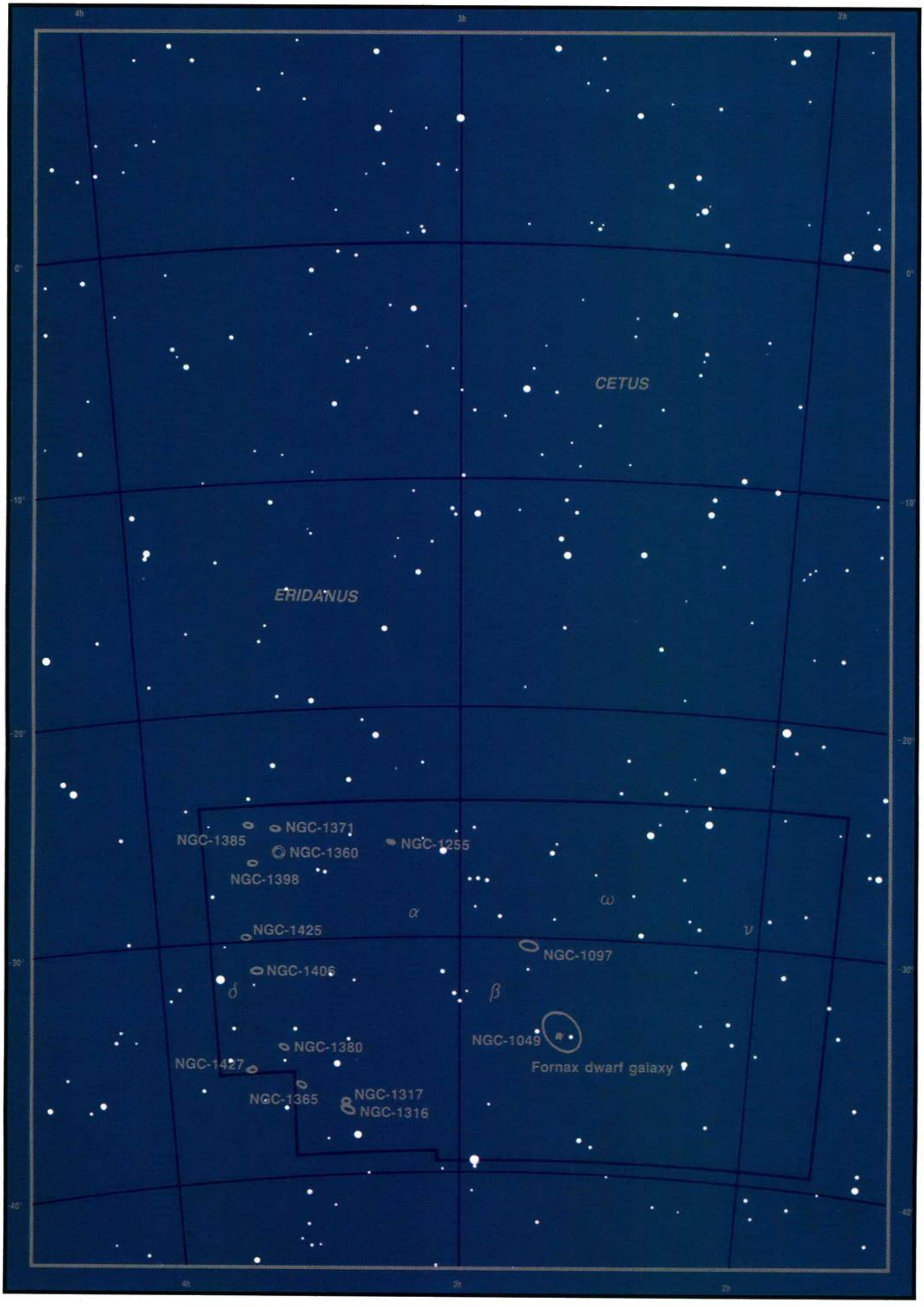
About 1.5° southwest of NGC-1371, **NGC-1360** forms an isosceles triangle with 6th- and 7th-magnitude stars. One of the southern sky's best planetary nebulae, this object has a remarkably high surface brightness that makes finding it in small telescopes relatively easy. There is no modern published magnitude for this object, but estimates place it at around 8th magnitude. The nebula measures 390″ — or 6.5 arcminutes — across and can be seen as a large disk of bluish green nebulosity in any telescope. An 8-inch scope reveals the 13th-magnitude central star.

| Object | M# | Type | R.A. (2000) | Dec. | Mag. | Size/Sep./Per. | H |
|---|---|---|---|---|---|---|---|
| Fornax dwarf | | 0 | 2h 39.9m | −34°32′ | $9.0_B$ | 20.0′x 13.8′ | dE3 |
| NGC-1049 | | ● | 2h 39.9m | −34°16′ | 13.0 | 0.4′ | |
| NGC-1097 | | §B | 2h 46.3m | −30°17′ | 9.3 | 9.3′x 6.6′ | S(B)b |
| NGC-1255 | | § | 3h 13.5m | −25°44′ | 11.1 | 4.1′x 2.8′ | Sc |
| NGC-1316 | | §B | 3h 22.7m | −37°12′ | 8.9 | 7.1′x 5.5′ | S(B)0pec |
| NGC-1317 | | §B | 3h 22.8m | −37°06′ | 11.0 | 3.2′x 2.8′ | SBa |
| NGC-1360 | | ■ | 3h 33.3m | −25°51′ | — | 390″ | |
| NGC-1365 | | §B | 3h 33.6m | −36°08′ | 9.5 | 9.8′x 5.5′ | SBb |
| NGC-1371 | | §B | 3h 35.0m | −24°56′ | $11.5_B$ | 5.4′x 4.0′ | S(B)a |
| NGC-1380 | | §L | 3h 36.5m | −34°59′ | $11.1_B$ | 4.9′x 1.9′ | S0 |
| NGC-1385 | | § | 3h 37.5m | −24°30′ | 11.2 | 3.0′x 2.0′ | Sc |
| NGC-1398 | | §B | 3h 38.9m | −26°20′ | 10.3 | 2.5′x 2.3′ | S(B)b$^-$ |
| NGC-1406 | | § | 3h 39.4m | −31°19′ | $12.6_B$ | 3.9′x 1.0′ | Sb$^+$ |
| NGC-1425 | | § | 3h 42.2m | −29°54′ | $11.7_B$ | 5.4′x 2.7′ | Sb |
| NGC-1427 | | 0 | 3h 42.3m | −35°25′ | $12.2_B$ | 2.8′x 2.0′ | E3 |

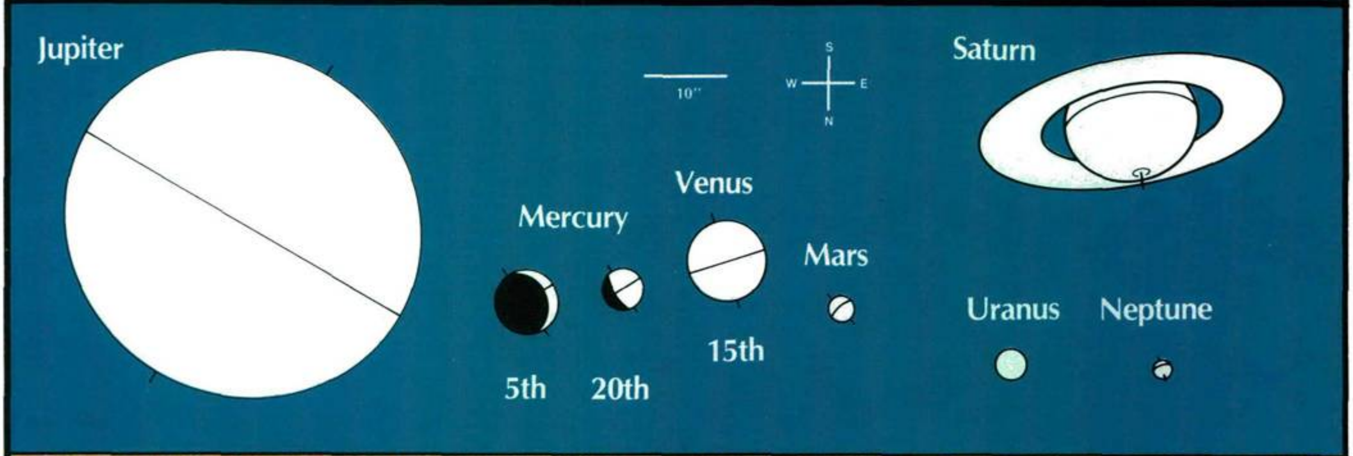
**H = Hubble type for galaxies**

**Subscript "P" denotes photographic magnitude; subscript "B" denotes blue magnitude.**

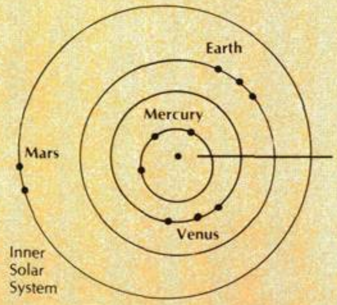
| | |
|---|---|
| ● | *Globular Star Cluster* |
| ■ | *Planetary Nebula* |
| § | *Spiral Galaxy* |
| §B | *Barred Spiral Galaxy* |
| §L | *Lenticular Galaxy* |
| 0 | *Elliptical Galaxy* |
| # | *Irregular or Peculiar Galaxy* |


4h
3h
2h
0°
-10°
-20°
-30°
-40°
CETUS
ERIDANUS
NGC-1371
NGC-1385
NGC-1360
NGC-1255
NGC-1398
α
ω
NGC-1425
ν
NGC-1097
NGC-1406
δ
β
NGC-1049
NGC-1380
Fornax dwarf galaxy
NGC-1427
NGC-1317
NGC-1365
NGC-1316

# Planetary Data November 1987


Jupiter
10''
S
W
E
N
Saturn
Venus
Mercury
Mars
15th
Uranus
Neptune
5th
20th

| | | Date | Mag. | Angular Size | % Illum. | Distance (AU) from: | | Longitude: | | R.A. (2000.0) | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Earth | Sun | Heliocentric | Ecliptic | | |
| **Sun** | | 1 | −26.8 | 32.3′ | — | 0.993 | — | — | 218°01.9′ | 14h 23.3m | −14°14.3′ |
| | | 15 | −26.8 | 32.4′ | — | 0.989 | — | — | 232°04.8′ | 15h 19.3m | −18°20.0′ |
| | | 30 | −26.8 | 32.5′ | — | 0.986 | — | — | 247°14.2′ | 16h 22.4m | −21°32.9′ |
| **Mercury** | ☿ | 1 | 2.9 | 9.6″ | 5% | 0.704 | 0.311 | 56°18.0′ | 210°15.0′ | 13h 53.2m | −11°09.1′ |
| | | 15 | −0.6 | 6.5″ | 65% | 1.037 | 0.339 | 140°33.3′ | 213°27.8′ | 14h 07.4m | −10°27.8′ |
| | | 30 | −0.7 | 5.1″ | 93% | 1.323 | 0.422 | 203°22.8′ | 234°40.6′ | 15h 30.1m | −18°01.3′ |
| **Venus** | ♀ | 1 | −3.9 | 10.4″ | 95% | 1.599 | 0.726 | 261°43.3′ | 236°29.7′ | 15h 36.6m | −19°30.4′ |
| | | 15 | −3.9 | 10.8″ | 93% | 1.549 | 0.728 | 283°53.2′ | 253°55.0′ | 16h 49.8m | −23°12.0′ |
| | | 30 | −3.9 | 11.2″ | 91% | 1.487 | 0.728 | 307°36.2′ | 272°34.1′ | 18h 11.3m | −24°42.6′ |
| **Mars** | ♂ | 10 | 1.8 | 3.8″ | 98% | 2.473 | 1.644 | 185°20.3′ | 200°58.1′ | 13h 18.7m | −7°23.2′ |
| | | 20 | 1.8 | 3.9″ | 98% | 2.419 | 1.637 | 189°50.3′ | 207°28.7′ | 13h 43.2m | −9°49.7′ |
| **Jupiter** | ♃ | 15 | −2.9 | 48.2″ | 100% | 4.081 | 4.957 | 27°10.9′ | 21°31.4′ | 1h 21.7m | 6°58.4′ |
| **Saturn** | ♄ | 15 | 0.5 | 15.2″ | 100% | 10.900 | 10.037 | 262°40.0′ | 260°11.7′ | 17h 17.7m | −21°54.4′ |
| **Uranus** | ♅ | 15 | 5.7 | 3.5″ | 100% | 20.065 | 19.241 | 266°30.4′ | 265°07.9′ | 17h 38.5m | −23°30.7′ |
| **Neptune** | ♆ | 15 | 8.0 | 2.2″ | 100% | 30.934 | 30.231 | 277°26.9′ | 276°21.4′ | 18h 27.3m | −22°19.3′ |
| **Pluto** | ♇ | 15 | 13.8 | 0.1″ | 100% | 30.606 | 29.676 | 219°59.8′ | 220°34.0′ | 14h 52.0m | −0°04.2′ |


Earth
Mercury
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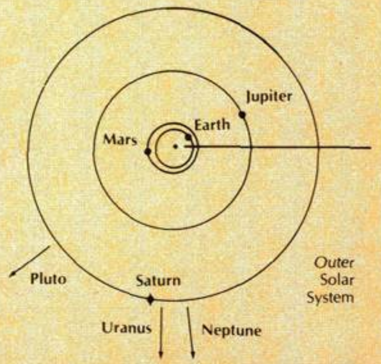
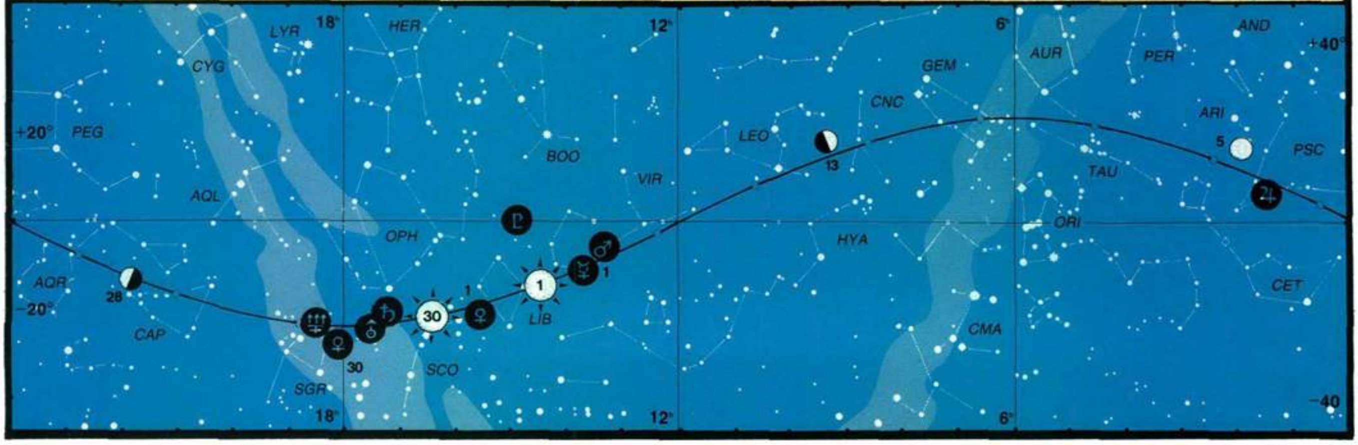
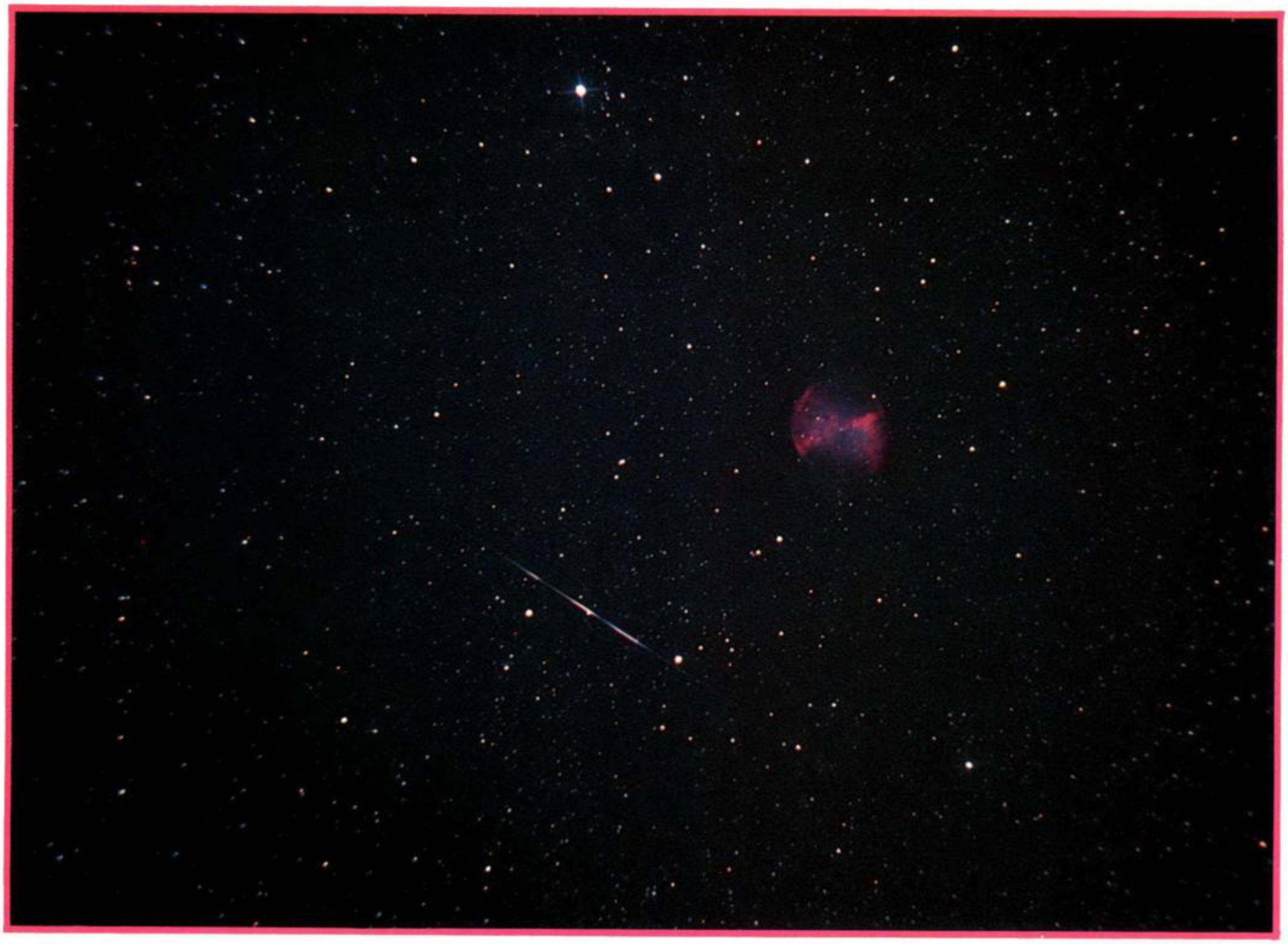
Inner
Solar
System


Jupiter
Earth
Mars
Pluto
Saturn
Outer
Solar
System
Uranus
Neptune

## Moon Data

Full Moon. . . . . . . . . . . . . Nov. 5 at 16h46m
Last Quarter. . . . . . . . . . Nov. 13 at 14h38m
New Moon. . . . . . . . . . . . Nov. 21 at 6h33m
First Quarter. . . . . . . . . . . Nov. 28 at 0h37m
Full Moon. . . . . . . . . . . . . . Dec. 5 at 8h01m
Last Quarter. . . . . . . . . . Dec. 13 at 11h41m
Apogee: Nov. 12 at 17h54m. . . 404,400 km
Perigee: Nov. 24 at 14h49m. . . 366,810 km


LYR
18°
HER
12°
6°
AUR
AND
+40°
CYG
GEM
PER
CNC
ARI
+20°
PEG
LEO
13
5
PSC
BOO
VIR
TAU
AQL
ORI
OPH
HYA
1
AQR
28
CET
−20°
30
LIB
CAP
CMA
SCO
SGR
18°
12°
6°
−40



**Rosy red, pink, and blue tones of nebulosity dominate this photo of the Dumbbell Nebula. Scott Hicks exposed Konica 400 ISO film for 20 minutes with his 12.5-inch f/8 reflector. A satellite left its mark as it tumbled through the field.**

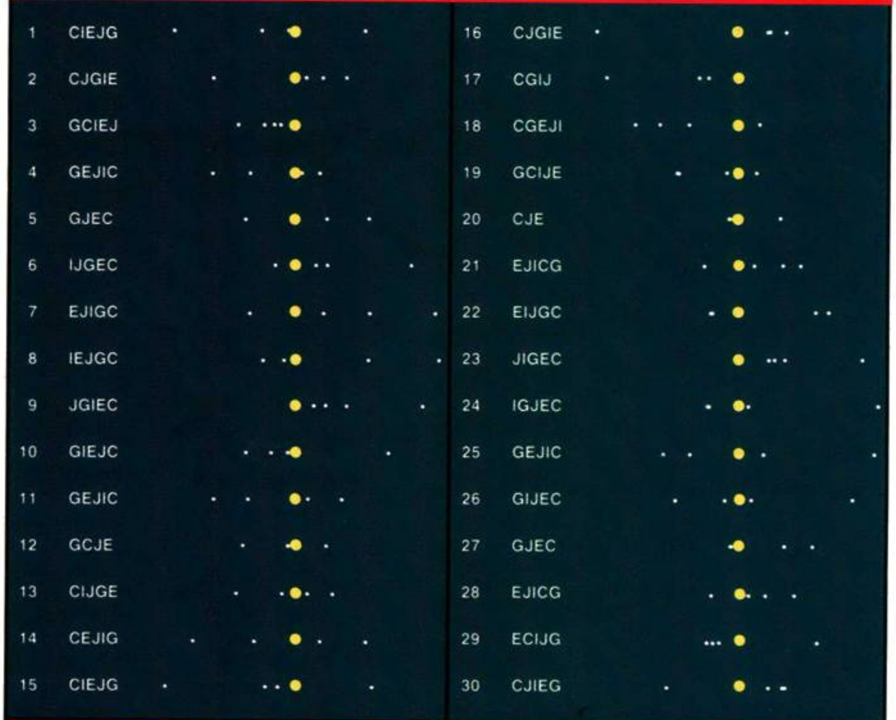
### Mercury

Throughout November Mercury is excellently placed for observation in the east-southeastern sky beginning about one hour before sunrise. Becoming visible in the first few days of the month, Mercury swiftly gains altitude until it reaches peak elevation (10°, forty-five minutes before sunrise) on the date of greatest elongation, November 13. Thereafter Mercury slowly drops and will vanish below the horizon during the first week of December.

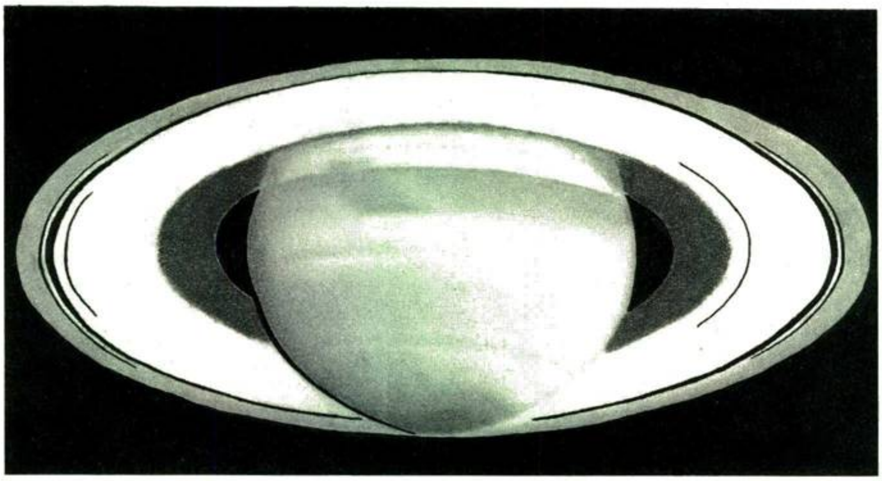
Getting a good telescopic look at the planet will mean finding an observing site with a clear view down to the east-southeastern horizon. Haze and thick layers of atmosphere will make the planet's image "swim" in your eyepiece even at low magnification. The only remedy is to keep observing while the planet rises higher and twilight grows brighter.

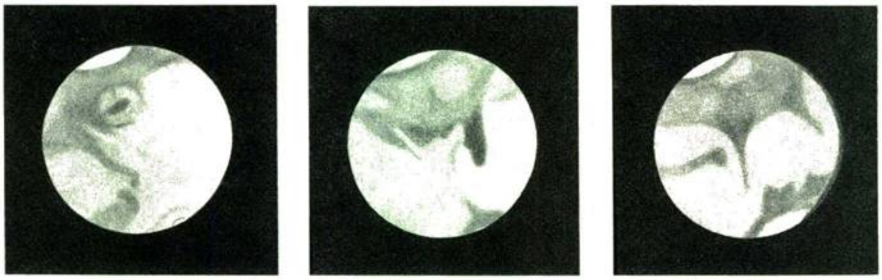
On November 5, Mercury is a 20 percent illuminated crescent glowing at magnitude 0.9 and measuring 8.6" across. After passing through "Quarter Moon" phase at greatest elongation, its disk becomes gibbous and smaller. On November 20, Mercury's image is 78 per-

## Satellites of Jupiter 2h00m UT


1 CIEJG
2 CJGIE
3 GCIEJ
4 GEJIC
5 GJEC
6 IJGEC
7 EJIGC
8 IEJGC
9 JGIEC
10 GIEJC
11 GEJIC
12 GCJE
13 CIJGE
14 CEJIG
15 CIEJG
16 CJGIE
17 CGIJ
18 CGEJI
19 GCIJE
20 CJE
21 EJICG
22 EIJGC
23 JIGEC
24 IGJEC
25 GEJIC
26 GIJEC
27 GJEC
28 EJICG
29 ECIJG
30 CJIEG

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)





Top: Saturn and Mars each offered fine planetary detail to observers during the summer of 1986. Michael E. Sweetman sketched Saturn on July 6, 1986, with his 10-inch f/16 Cassegrain scope at 347x. Sweetman noted that the seeing was very steady that night.

Above: Throughout June and July 1986 Gary Rosenbaum made a series of sketches of Mars with his 8-inch f/6.1 reflector at various magnifications. He used a Wratten 25 red filter to bring out surface detail on the disk. The drawing at left was made on June 19, the center drawing on July 6, and the sketch at right on July 30.

cent lit, shines brilliantly at magnitude −0.7, and spans 5.8″.

### Venus

Although it shines brightly and is easy to see in the southwest shortly after sunset, Venus doesn't attain a high elevation this month. Telescopic views will therefore be about as murky and distorted as those of Mercury. But because Venus' orbital motion is more gradual than Mercury's, the changes in Venus' appearance also occur more slowly. Over the month Venus remains at magnitude −3.9, and its gibbouslike disk grows only slightly, from 10.4″ across to 11.3″.

### Mars

This month Mars is high enough in the southeastern sky for good telescopic viewing, but the planet doesn't offer much even at high magnification. Only twice the size of our Moon, Mars is about 2.5 astronomical units (about 233 million miles) away. Therefore its disk measures a mere 3.9″ across.

If you observe Mars steadily for a week or more, you will begin to notice more detail as your eye becomes accustomed to spotting subtle shades on the planet's surface. But you will have difficulty seeing anything except a few dusky markings.

### Minor Planets

1 Ceres (magnitude 8.8) is following an eastward path in Sagittarius. It passes about 2° south of Nunki, the brightest star in the "Milk Dipper" asterism, around the middle of the month. Ceres' positions:

1st: 18h 34m 13s, −28° 29.7′
10th: 18h 47m 34s, −28° 21.0′
20th: 19h 03m 03s, −28° 05.8′
30th: 19h 19m 04s, −27° 44.5′

Ceres sets around 7 p.m. local time on the 15th.

2 Pallas (10.3) is moving eastward in northern Ophiuchus. Its positions:

1st: 17h 03m 24s, 5° 48.0′
10th: 17h 15m 37s, 5° 00.4′
20th: 17h 29m 31s, 4° 17.0′
30th: 17h 43m 40s, 3° 43.9′

Pallas sets about 8 p.m. local time on the 15th.

3 Juno (9.5) is moving eastward out of Capricornus into Aquarius. Its positions:

1st: 21h 45m 36s, −13° 01.1′
10th: 21h 53m 11s, −13° 10.2′
20th: 22h 03m 42s, −13° 03.1′
30th: 22h 16m 09s, −12° 38.8′

Juno sets around 11:30 p.m. local time on the 15th.

4 Vesta (7.6) lies in Cancer, south of the Beehive Cluster, M-44. On November 23, Vesta passes 29′ north of 3.9 magnitude Delta (δ) Cancri. Its positions:

1st: 8h 29m 43s, 18° 44.4′
10th: 8h 37m 00s, 18° 36.1′
20th: 8h 43m 05s, 18° 35.9′
30th: 8h 46m 42s, 18° 47.6′

Vesta rises about 10:30 p.m. local time at mid-month.

106 Dione (12.0) lies near the Taurus-Aries border and is moving retrograde; it is at opposition on November 23. Its positions:

1st: 4h 13m 16s, 20° 14.6′
10th: 4h 06m 34s, 20° 13.2′
20th: 3h 57m 59s, 20° 08.2′
30th: 3h 49m 05s, 20° 00.9′

Dione is visible all night this month.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star map (*Sky Atlas 2000.0* or *Uranometria 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that moved is the

asteroid. (All minor planet coordinates are for the epoch 2000.0.)

### Jupiter

At opposition last month, Jupiter is already visible in the east as twilight darkens in November. It appears nearly as large as in October and is just as easy to view. (See Gazer's Gazette, page 62.)

No matter what size instrument you have, Jupiter presents a fascinating look at a miniature solar system. Its four bright Galilean moons revolve about Jupiter as the planets revolve around the Sun. To keep track of which point of light is which moon, use the "Satellites of Jupiter" chart on page 107. After a few nights of viewing, you'll quickly pick out swift-moving Io and Europa from the slower Ganymede and Callisto.

### Saturn

Saturn is visible during the first week or so of November, but thereafter it lies too low for adequate viewing. Its appearance is much as it has been all year: the rings are 34" across and their northern side is tipped 26° to our line of sight.

### Uranus

Uranus is a little higher than Saturn this month but is slowly vanishing from view. On the 24th, Venus passes just under a degree south of Uranus. Using a low magnification eyepiece, scan 56" north of Venus and look for a greenish, 6th-magnitude disk 3.5" across.

### Neptune

Neptune is higher than Uranus but lies amidst a crowded starfield in Sagittarius. After locating Lambda (λ) Sagittarii, sweep north about 3° and then move 1/2° west. Neptune has an 8th-magnitude grayish disk 2.2" across.

### Pluto

November 2 is the date of Pluto's conjunction with the Sun. Although thereafter Pluto lies in the morning sky, it won't be high enough in the sky to be found for a few months yet.

**This photo of the winter sky above Mars Hill in Flagstaff, Arizona, nets Brian Skiff this month's $100 "Best Astrophoto" award. Skiff used a 15mm f/2.8 fisheye lens and a 60-second exposure on Kodachrome 200 film. Visible above Lowell Observatory's 21-inch photometric telescope are the Moon, Mars, the Pleiades, and the Hyades, as well as the constellations Canis Major, Canis Minor, Orion, Taurus, Perseus, and Auriga.**

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| Electric Focuser, for PS-C8 II | (List: $ 150.00) | **$ 99.95** |
| Electric Declination Motor, for PS-C8 II | (List: $ 130.00) | **$ 89.95** |
| PIGGYBACK Bracket for camera, for C8 Tubes | (List: $ 50.00) | **$ 36.95** |
| T-Adapter for camera, for C8 Tubes | (List: $ 40.00) | **$ 29.95** |
| Off-Axis Photographic Guider System, complete, for C8 Tube | (List: $ 250.00) | **$174.95** |
| Counterweight Bar Assembly, with weights, for C8 Tube | (List: $ 150.00) | **$ 99.95** |

**C11, StrBrt, W&T** List:$ 7,570.00 **.... $ 3,749.95**

**C14, StrBrt, W&T** List:$14,770.00 **.... $ 7,599.95**

## SUPER POLARIS C8

The SP-C8 is *still* your best dollar-value in a full-featured, significant-aperture, astronomical telescope. The complete kit includes *exactly the same* diffraction-limited 8" Schmidt-Cassegrain telescope tube assembly used on Celestron's much more expensive PwrStar C8 (shown at left), along with a high-quality German-type Equatorial Mount and adjustable Tripod that is loaded with standard features and capabilities, such as built-in *worm-gear* slow-motion controls on *both* axes of motion, setting circles and clutches on both axes, built-in micrometer azimuth and latitude adjusters, bubble level, and *built-in illuminated-reticle polar-alignment telescope!*

### STANDARD FEATURES & FACTORY-SPECIFIED EQUIP

Complete f/10 telescope tube assembly (8" aperture, 2000mm focal length), with Celestron's world-famous, hand corrected, diffraction-limited, laser tested, individually certified ("Gold Standard") optical system; widefield 6x30mm straight-thru finderscope; 1.25" visual accessory holder; high-brightness, enhanced-coatings mirror type 1.25" star diagonal; 26mm (77x), 1.25" barrel, multi-coated, premium-grade Plossl eyepiece; piggyback camera bracket; hand strap for holding telescope tube assembly during setup and takedown; quick-mount slider bracket for mounting and balancing scope tube; German-type equatorial mount with: (1) full 360° worm-drive slow-motion/manual-positioning controls on both axes (with anti-backlash adjustments), (2) setting circles on both axes, (3) vernier brake/clutches on both axes, (4) micrometer latitude adjustment (0-90°!) with latitude scale, (5) micrometer azimuth adjustment, (6) bubble level, (7) built-in (in the polar axis shaft) illuminated-reticle polar alignment telescope, (8) sliding-type counterweight (for quick adjustment) on quick-disconnect counterweight shaft (for quick setup and takedown), and (9) vibration-damping adjustable wooden tripod with accessory tray; foam-lined carrying case for telescope tube assembly; dust covers for optical apertures; instruction manual; limited lifetime warranty.

**SP-C8** .................. (List: $1,620) **........ $ 949.95**

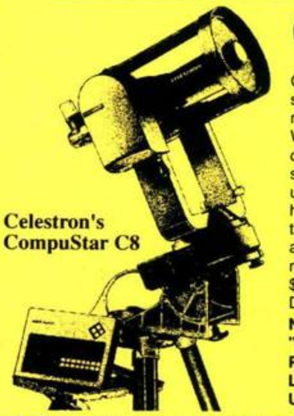
**SP-C8 StrBrt** ........ (List: $1,800) **........ $1,099.95**

FREE FREIGHT! (UPS Ground) for the SP-C8's shown above

### Accessories for SP-C8 Telescopes

| | | |
|---|---|---|
| 8x50mm St-Thru/RtAngle Finder & Mounting Bracket | (List: $ 200.00) | **$ 99.95** |
| 1-Axis DC MotorDrive/Corrector | (List: $ 220.00) | **$149.95** |
| 2-Axis DC MotorDrive/Corrector | (List: $ 380.00) | **$269.95** |
| 2-Axis DC SKYSENSOR Computer Drive/Corrector | (List: $ 950.00) | **$599.95** |
| DEWSTAR LensShade/DewShield, for C8 Tubes | (List: $ 24.00) | **$ 19.95** |

## CompuStar



**Celestron's CompuStar C8**

Celestron's *CompuStar* computer-controlled telescopes are the most awesomely powerful instruments available to the amateur astronomer today. With coordinates and data on over 8,000 astronomical objects stored in its memory, and high-rate slew speeds, CompuStar can take you on a tour of the universe that must be experienced to be comprehended. Even a partial listing of CompuStar's features, functions and capabilities is too extensive to attempt here. Please write or call for additional information, pricing and delivery estimates, or send $10.00 cash, U.S., for our CompuStar Introductory Documentation Package.

**NOTE: WE SPECIALIZE IN CompuStar RETROFIT "COMPUTERIZATION" OF C11's AND C14's. PLEASE CONTACT US REGARDING PRICE, DELIVERY AND OTHER DETAILS INVOLVED IN UPGRADING YOUR C11 OR C14 TELESCOPE.**

**CC8, StrBrt, W&T** .. (List: $ 6,680.00) **.. Call**

**CC11, StrBrt, W&T** .. (List: $13,570.00) **.. Call**

**CC14, StrBrt, W&T** .. (List: $21,570.00) **.. Call**

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# CELESTRON'S C11 & C14

Actual C14 photo, M22

### SPECIFICATIONS

| | C14 | C11 |
|---|---|---|
| Clear Aperture | 14″ | 11″ |
| Focal Length | 3910mm | 2800mm |
| Photographic Speed | f/11 | f/10 |
| Magnification Range | 50X-840X | 40X-660X |
| Weight | 116# | 57# |
| Drive | Worm | Worm |
| Tube | Aluminum | Aluminum |
| Mount | Swing through fork | |
| Finder | 8X50 Polaris | |
| # of Eyepieces | 4 | 1 |
| Focuser size | 2″ | 2″ |
| Setting Circles | Yes | Yes |
| Slow Motion | Yes | Yes |
| Limiting Magnitude Resolution | 15 | 14.5 |

Unrivaled light gathering ability in a quality, portable telescope. The ideal instrument for serious astronomic pursuits. Astonishing close-ups of the moon, remarkable views of the planets, voyages across countless light years to distant star clusters, galaxies and nebulae.

Experience the world's largest aperture catadioptric commercially produced telescopes. Computer designed, laser collimated, Starbright® coated Schmidt Cassegrain instruments built for a lifetime of visual and photographic applications.

Computer controlled models (Compustar 11 and 14) also available each with over 8000 objects in memory.

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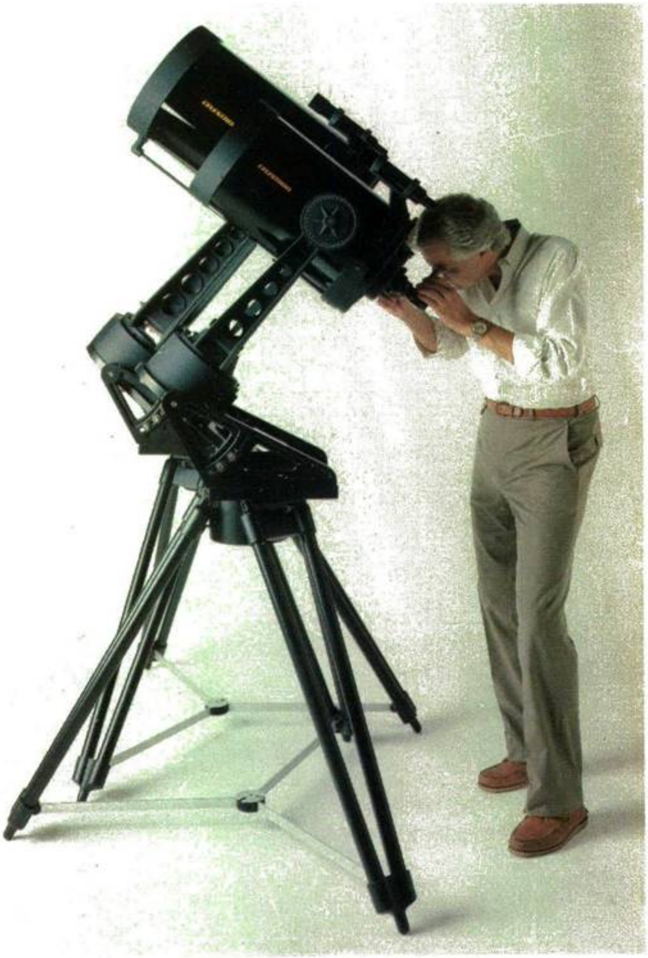

C11 in foreground, C14 in background

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